

A BIOSTRATIGRAPHIC STUDY
OF JURASSIC CALCAREOUS NANNOFOSSILS
FROM PORTUGAL AND GREAT BRITAIN

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ABSTRACT

It is intended that this study will contribute to the growing record of knowledge on the stratigraphic distribution of Jurassic calcareous nannofossils in order to extend their biostratigraphic and correlatory use.

Over two hundred samples from six sections in Jurassic sediments from Portugal were examined in light and scanning electron microscopes. The taxonomic aspects of the flora were studied and the stratigraphic ranges of the species and their abundances were recorded. Four of the sections cover the Lower and Middle Jurassic and these are in fully marine facies. One of the Upper Jurassic sections, Torres Vedras, is also in marine sediments but the second, the Alcanede-Carvalhos Road Section reflects part of a regressive phase which culminated in the deposition of brackish water and non-marine sediments in the basin to the north of the River Tagus during the Upper Jurassic (or Lusitanian stage of Portuguese geology).

The stratigraphic position of the two Upper Jurassic sections is not well known. It was hoped that the examination of the calcareous nannofossils in fifteen samples from a Callovian to Oxfordian section on the Isle of Skye and in 75 samples from three Upper Jurassic cores in the western North Atlantic would enable correlation of species and thus resolve the question of the stratigraphic position of the Upper Jurassic Portuguese sections. In fact, it only proved possible to locate the Torres Vedras Section which was of Callovian to Lower Kimmeridgian age.

In addition, fourteen samples from a Triassic to lowermost Jurassic (Hettangian) section from Watchet in North Somerset, England

were examined in a preliminary investigation of the early calcareous nannofossil record. The group is generally accepted as first appearing in the Lower Jurassic but the Rhaetian samples from Watchet contained a limited assemblage which showed that a pre-Jurassic record exists. Further evidence for this was found in a reconnaissance survey of Triassic sediment from Italy.

Finally, a biostratigraphic scheme is developed from the results obtained in this study and from other published data.

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1. INTRODUCTION

1.1. Calcareous nannofossils

Calcareous nannofossils constitute a heterogeneous group of small, calcareous objects that range in size from approximately 0.25 μm to 20 μm (0.00025 mm to 0.02 mm). The collective name, calcareous nannofossils, includes coccoliths, nannoconids, braarudosphaerids, discoasters and some other small, calcareous objects of uncertain taxonomic affinity.

Coccoliths are the best known and most common type of calcareous nannofossil. Their discovery can be attributed to EHRENBURG who, in 1836, described some minute, inorganically precipitated calcium carbonate bodies and later, in 1840, published descriptions and illustrations of chalk samples in which he noted "elliptical granular platelets". In 1858 HUXLEY discovered some minute calcareous bodies in deep sea sediment from the North Atlantic ocean and later (1868), in describing his results, he named these bodies coccoliths. WALLICH (1860) also recognised coccoliths in deep sea sediments. In addition he discovered spherical bodies which seemed to be made up of a number of coccoliths and he named them coccospheres. SORBY (1861) suggested that coccoliths were not inorganically precipitated but had an organic origin and that the coccospheres might be "an independent organism". However, no attempts at a formal, systematic study of these fossils were made at this stage, beyond noting their occurrence and speculating on their origin.

The study of the group remained more or less dormant until the 1930's when KAMPTNER and DEFLANDRE began their investigations. Since then coccoliths have been intensively investigated and their study has been encouraged by improved optical equipment and the application of electron microscopy.

Coccoliths are now well known because improved techniques in oceanic sampling have enabled studies to be made of the living organism. They are complexly constructed, button-shaped skeletal elements produced by unicellular, biflagellate, golden-brown algae called Coccolithophores. In the living organism the coccoliths are arranged in the form of a hollow sphere, the coccosphere, just within the cell membrane. The majority of the coccolithophorid algae are marine but some are known to inhabit fresh or brackish waters. The fossil record has shown that from their earliest appearance in the Lower Jurassic coccoliths demonstrate an increasingly wide diversity of structure and this, together with the planktonic mode of life of the coccolithophorid algae, makes coccoliths excellent biostratigraphic and correlatory indicators.

Nannoconids are fossils of uncertain taxonomic position as they are not known in the present day oceans. Originally described from the Upper Jurassic and Lower Cretaceous of central and southern Europe, nannoconids are stratigraphically diagnostic microfossils for parts of the Mesozoic. They are small, cone shaped objects made up of a series of calcareous plates arranged in layers. Although they are normally larger than coccoliths they are recovered from sediments by the same techniques that are used for the extraction of coccoliths. They are, therefore, included in the calcareous nannofossils. The pentolith-forms, braarudosphaerids, are included in the calcareous nannofossils for the same reason. The name "Disco-aster" was first used by TAN SIN HOK (1926) as a morphological term. It represents the latin translation of the german "Scheibensterne" and is used to describe the stellate calcareous nannofossils whose occurrence is restricted to Neogene deposits.

1.2. The research methodology

The main purpose of this study is to extend the biostratigraphic and correlatory use of calcareous nannofossils in the Jurassic. The work also includes a reconnaissance study of the previously little studied pre-Jurassic record of calcareous nannofossils.

The diagram in Text Fig. 1 demonstrates the stratigraphic distribution of the sections studied in this work and Text Fig. 2 illustrates their geographic distribution.

The Rhaetian and lower part of the Lower Jurassic (Hettangian) are examined in a section at Watchet in North Somerset. The interval from the Lower Sinemurian (Lower Jurassic) to the Kimmeridgian (Upper Jurassic) is covered by several Portuguese sections (Brenha Road, Peniche, Cap Mondego, Alcanede-Carvalhos Road, Torres Vedras) and the Callovian/Oxfordian boundary interval is also studied in a section from Staffin on the Isle of Skye.

The Lower Jurassic part of the Brenha Road Section from Portugal has already been described by the author in a study which formed part of a M.Sc. Degree at the University of London (1975) and in a recent publication (HAMILTON 1977) which appears at the back of this volume. It is only included here for the purposes of completion and for correlation with the Lower Jurassic section in the neighbouring Peniche region and in the relevant literature.

In addition, some Upper Jurassic samples from the Deep Sea Drilling Project cores 99A, 100 and 105 in the western North Atlantic are examined for correlatory purposes. These sediments have already been analysed by the Deep Sea Drilling Project shipboard scientists on the Glomar Challenger and in post-cruise, land based studies, so that the work is not original. However, the Upper Jurassic in Portugal is

Stage and Zone											
Berriasian											
Tithonian											
Kimmeridgian	P. pallasoides										
	P. rotunda										
	P. pectinatus										
	S. wheatleyensis										
	Subplanites sp.										
	G. gigas										
	G. gravesiana										
	A. pseudomutabilis										
	A. mutabilis										
	R. cymdoce										
	P. baylei										
Oxfordian	R. pseudocordata										
	D. decipiens										
	P. cautisnigrae										
	P. plicatilis										
	C. cordatum										
Callovian	Q. mariae										
	Q. lamberti										
	P. athleta										
	E. coronatum										
	K. jason										
Bathonian	S. calloviense										
	M. macrocephalus										
	C. discus										
	C. hollandi										
	O. aspidoides										
Bajocian	T. subcontractus										
	G. proglacilis										
	Z. zigzag										
	P. parkinsoni										
	G. garantiana										
Toarcian	S. subfurcatum										
	S. humphriesianum										
	S. sowerbyi										
	G. concavum										
	L. murchisoni										
Pliensbachian	T. scissum										
	L. opalinum										
	D. levesquei										
	G. thouarsense										
	H. variabilis										
Sinemurian	H. bifrons										
	H. falciferum										
	D. tenuicostatum										
	P. spinatum										
	A. margaritatus										
Hettangian	P. davoel										
	T. ibex										
	U. jamesoni										
	E. raricostatum										
	O. oxynotum										
Rhaetian											

Watchet

Brenha Road

Peniche

Cap Mondego 1.

Cap Mondego 2.

Isle of Skye

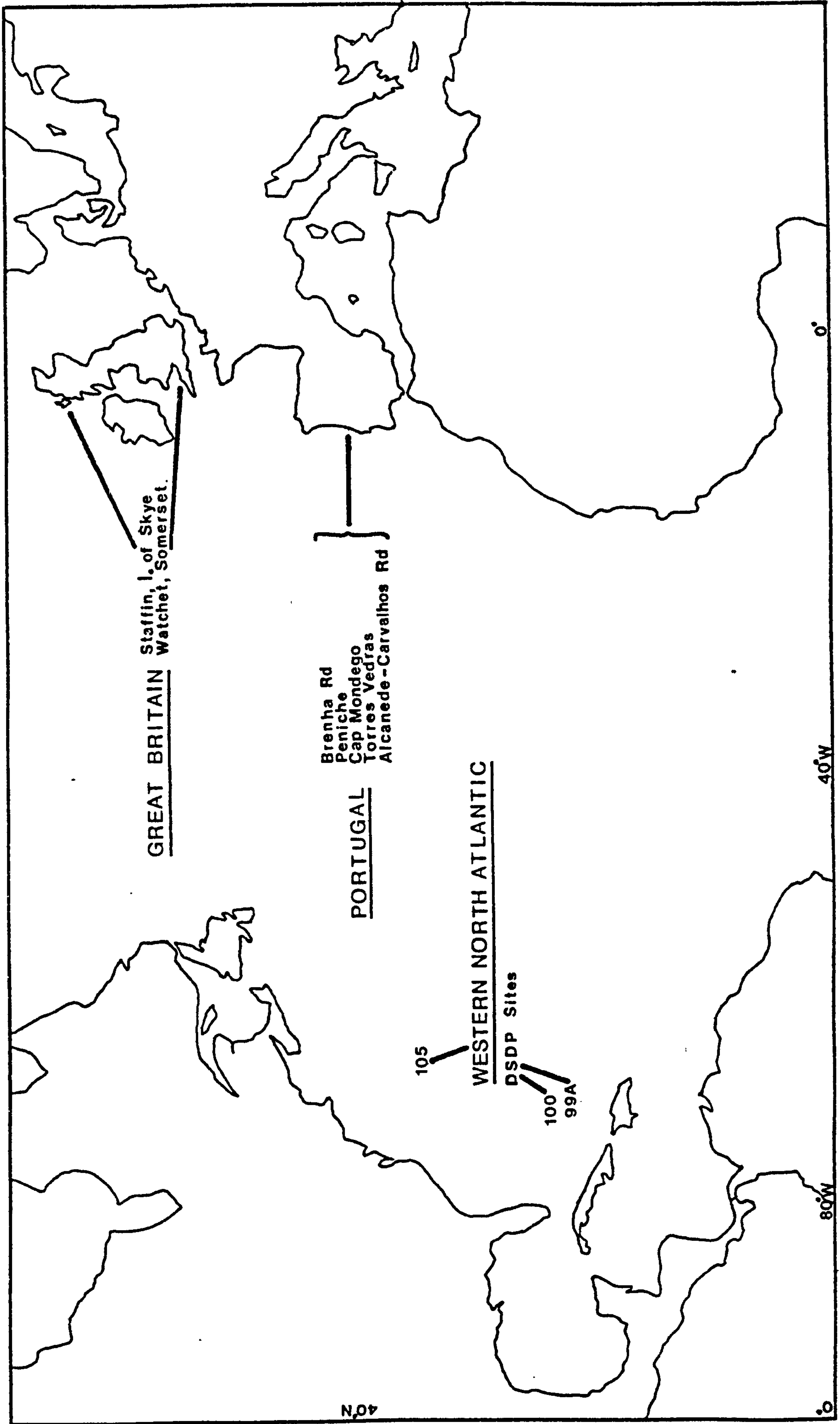
T. Vedras + Al.-Carv. Road

DSDP 105

DSDP 100

DSDP 99A

Text Fig.1 Stratigraphic Distribution of Studied Sections.



Text Fig. 2 Geographic Distribution of Sampled Areas.

poorly known and the sampled sections are not well located in terms of the established stratigraphic system. It is hoped that a comparison of the calcareous nannofossils with the assemblages from the Deep Sea Drilling Project cores will clarify the stratigraphic position of the Portuguese sections, particularly with respect to the Lusitanian stage and its relationship with the established chronostratigraphic scheme for the Jurassic.

The work includes a detailed discussion on the techniques employed in the study of calcareous nannofossils for the purposes of biostratigraphy. The methods used by the author are compared with those described in the literature.

A comparison of the calcareous nannofossils from the geographically scattered sampled localities demonstrates that the assemblages show little provincialisation. Thus, a synthesis of the available data is possible which enables a biostratigraphic scheme to be developed. The calcareous nannofossil assemblages are compared with the distributions recorded by other workers. The existing calcareous nannofossil biostratigraphic schemes for the Jurassic are also applied to the results obtained in this study. From this, an alternative biostratigraphic scheme is developed which aims to accommodate the distributions found by other workers and the results obtained here. In this way it is hoped that a broadly applicable biostratigraphic scheme will be formed which can extend the use of Jurassic calcareous nannofossils.

The work also includes a review of the phenomena which can alter a calcareous nannofossil assemblage from the natural association of calcareous nannoplankton. An understanding of these factors assists in the interpretation of fossil assemblages and thus increases the use of calcareous nannofossils in biostratigraphy.

2. PREPARATION TECHNIQUE

2.1. The method employed in this study

The method used for the preparation of the studied samples was adapted from the techniques described by EDWARDS (1963) and HAY (1965). The author considers that it is important to include a full description of the method used in this study. A comparison with other methods described in the literature is also given here since different methods may produce differences in the recovery of the fossil flora.

Most of the samples that were collected in Portugal were marls, the sampled sections from Watchet and Skye were predominantly in shales and the Deep Sea Drilling Project sediment was mainly in soft limestones. The same preparation technique was used for all these rock types.

A small, clean piece of sediment of not more than 1 cc in size is gently crushed with light blows from a hammer. If the sample shows signs of weathering the surfaces may be cleaned before crushing by scraping with a penknife. The fragments of the sample are then put into a beaker with approximately 25 mls of a 10% solution of sodium hexametaphosphate (Calgon) and left to soak for 24 hours. The Calgon serves to disaggregate the clay particles in the sediment and ensure an even distribution of particles in the final mount. After 24 hours the sediment is normally broken down to a fine deposit. The beaker is then put into an ultrasonic agitator for 8 - 10 minutes depending on the condition of the sediment after soaking in the Calgon. Hard shales and hard limestones sometimes do not respond to soaking and have to be agitated for longer periods of time in order to break them up. After agitation the beaker is left to stand for one minute and then the suspended material is transferred into a second beaker. The residue is discarded.

The suspension is divided equally between two centrifuge tubes and is centrifuged at the following rates:

1.350 r.p.m. for 15 seconds, after which the centrifuge
is stopped quickly

2.850 r.p.m. for 1 minute, after which the centrifuge is
left to stop itself

(Following the method used in the Micropalaeontology Unit
at University College.)

After each centrifugation the supernatant liquid is discarded and the residue is kept. This is washed with distilled water and repeatedly centrifuged at the faster rate until the supernatant liquid is quite clean. The final, clean residue is resuspended with distilled water and is stored with two drops of ethyl alcohol until it is required.

The sample is briefly examined with the light microscope (Zeiss Photomicroscope) in a smear slide. These are made by drying some of the suspension on a glass slide and sticking a cover slip to this with Canada Balsam. The cover slip enables examination of the sample at higher magnifications using oil immersion.

If the sample contains a good abundance of calcareous nannofossils (more than one or two in each field of view) it may then be selected for examination under the scanning electron microscope. For this, the suspended material is dried onto a small, round glass coverslip which is then stuck to a scanning electron microscope stub with a conductive glue (Colloidal Silver). The dried suspension is coated with a thin layer of gold in a Polaron S.E.M. Coating Unit and is then ready to be examined. For this study a Cambridge Instrument's S4 Scanning Electron Microscope was used. Under the high magnification and good

resolution produced by this machine the structural details of calcareous nannofossils are clearly visible and this enables specific identification.

Once the specimens have been identified in the scanning electron microscope the information on structure must be used to identify the specimens in the light microscope where magnification and resolution are greatly reduced.

Using the light microscope, species abundance is recorded by counting the number of specimens of each species in three hundred fields of view in a smear slide at a magnification of 1200x. Following HAY (1970) species abundance is determined by dividing the total number of specimens of each species by 300 and is recorded as the logarithm of abundance.

Abundant	= 1	= 10's of specimens in each field of view
Very common	= 0	= 1 specimen in each field of view
Common	= -1	= 1 specimen in 10 fields of view
Rare	= -2	= 1 specimen in 100 fields of view

In the range charts the abundance is represented by lines of different thickness.

The preparation technique described here has proved to be a reliable, consistent method which produces a good abundance and wide variety of clean calcareous nannofossils. However, the method necessitates that the sample be completely processed within two weeks, since it has been found that the full calcareous nannofossil assemblages are not preserved after a long period in the storage jars.

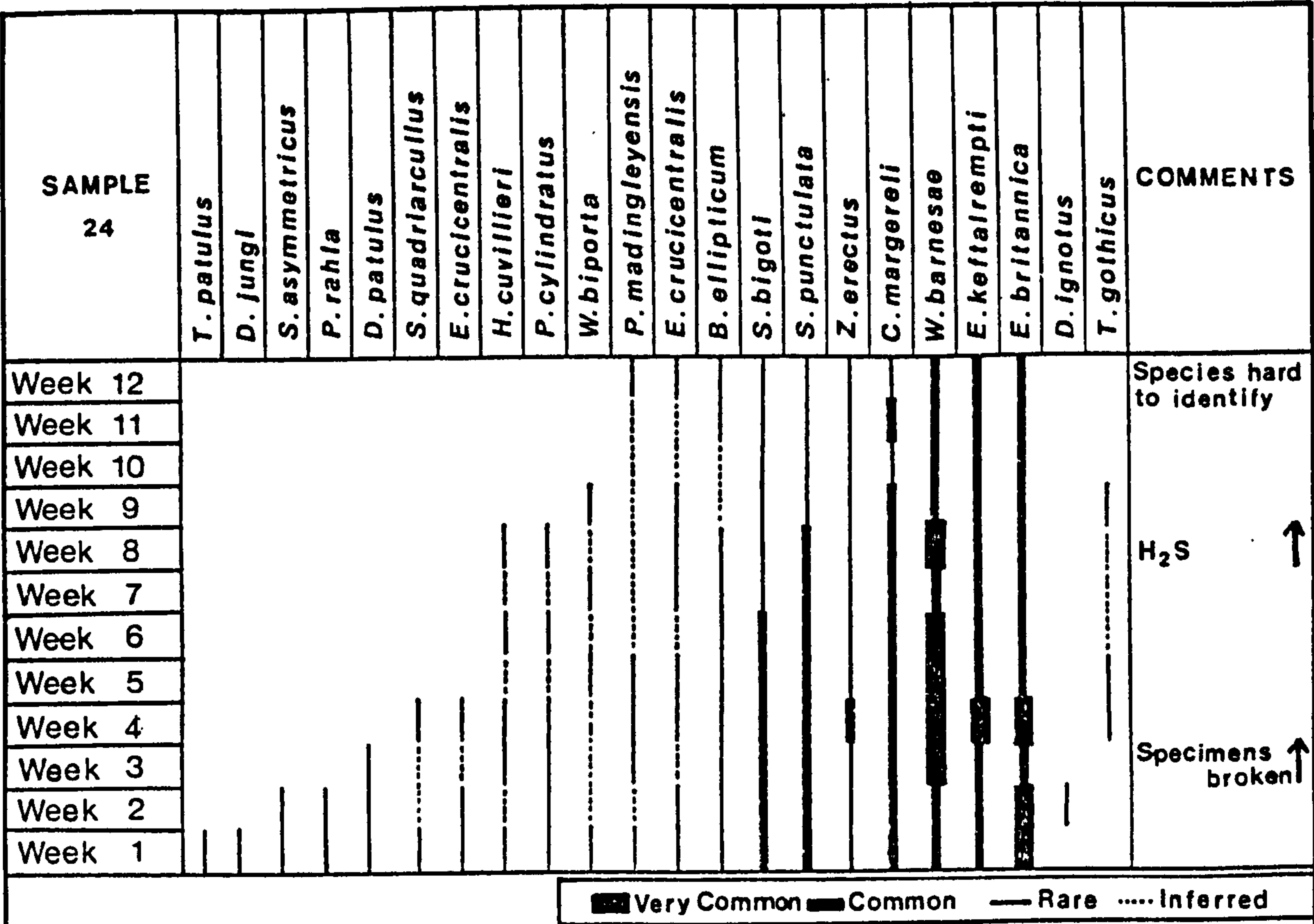
2.2. Experimentation

A simple experiment was carried out to determine the length of time over which samples were suitable for examination before the deterioration of the assemblages.

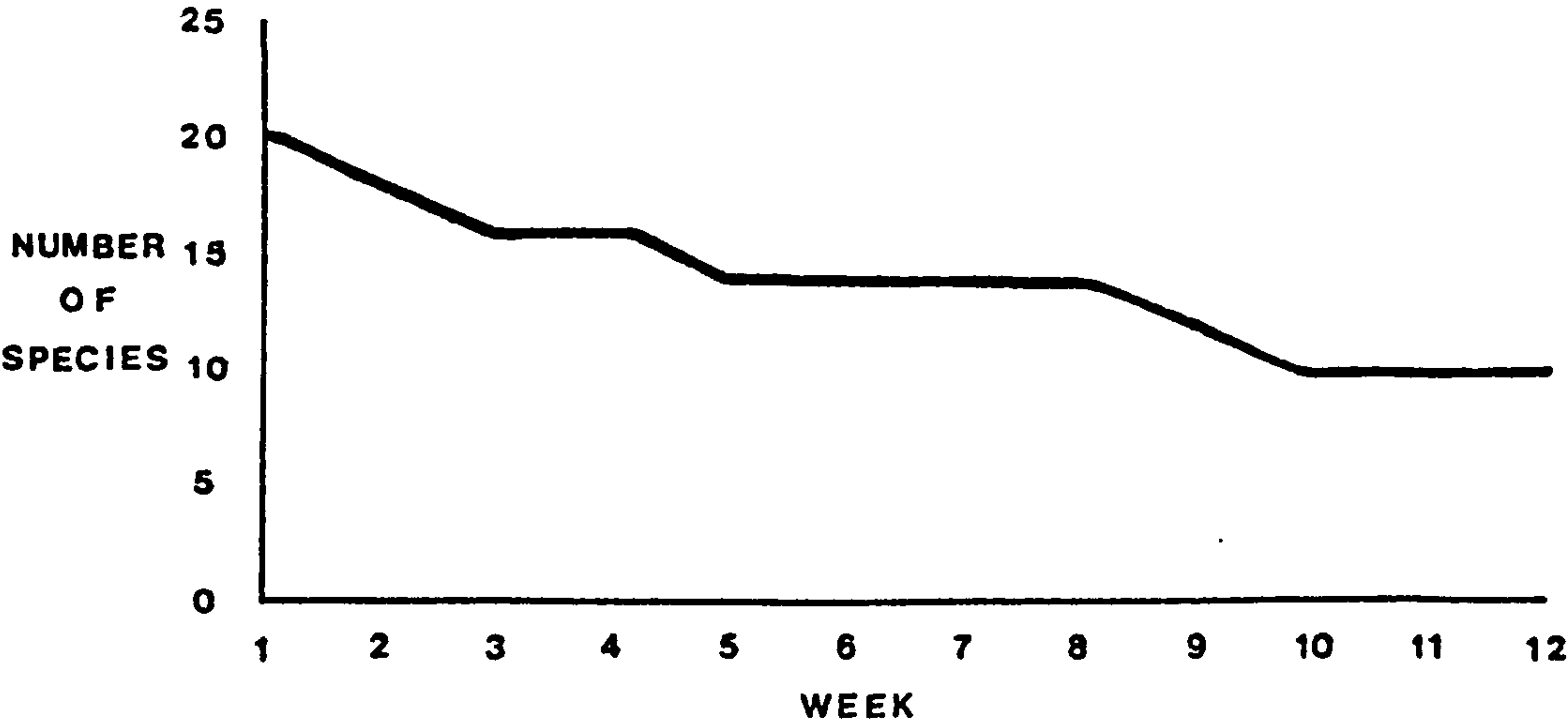
A sample which had previously been found to contain a good abundance of calcareous nannofossils was selected (Sample No. 24 from the Staffin Bay Section, Isle of Skye). The sample was processed according to the method described above and the clean residue was stored in a jar with two drops of ethyl alcohol. One smear slide of this sample was made every week for a period of twelve weeks. The species abundance in each of the slides was recorded by making counts of the number of specimens of each species in 300 fields of view.

The results are drawn up in the form of a range chart in Text Fig. 3a and the overall change in the assemblages is represented in the graph in Text Fig. 3b. These diagrams show that there is a considerable decrease in the number of species recorded in the smear slides over the 12 week period.

Clearly, the assemblages are dominated by Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968, Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 and Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968. The relative proportions of these species do not change over the experimental period. Cyclagelosphaera margereli NOEL 1965 is also an important species although it does not dominate the assemblages in the latter three weeks. Of the remaining species that are found in all the slides, Stephanolithion bigoti DEFLANDRE 1939 and Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938 show a decrease in abundance over the period. However, Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975, Ellipsagelosphaera crucicentralis



Text-fig.3a Chart showing Species Recorded during the Experiment.



Text-fig.3b Graph showing the Reduction in the Number of Species Recorded during the Experiment.

Text Fig.3 Results of the Experiment carried out on Sample 24.

MEDD 1971, Polypodorhabdus madingleyensis BLACK 1968 and Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971 do not show any significant trend, being found sporadically throughout the 12 week period. Of the species which are not found throughout the experimental period only a few, Ethmorhabdus gallicus NOEL 1965, Hexapodorhabdus cuvillieri NOEL 1965 and Podorhabdus cylindratus NOEL 1965, can be considered to be significant. The rest are normally very rare and their absence might equally be attributed to their rarity as to their having been destroyed. The occurrences of Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968 and Tetralithus gothicus DEFLANDRE 1959 are somewhat inconsistent with the general trend but since the species are found sporadically and are not important constituents of the assemblages no further discussion is warranted.

In addition to a decrease in the number of species over the experimental period, a change in the preservation of the specimens was noted. For instance, in the third week it was found that the smear slide was not as clean as the previous two slides had been and that the assemblages contained several broken specimens. Also, specimens of Stephanolithion bigoti were beginning to show some thickening of their outer spines. This feature, which is further discussed in the section on preservation (Chapter 11.2) became more apparent over the remaining weeks. The progressive thickening of the outer spines of Stephanolithion bigoti is clearly demonstrated in Plate 8 (Figure 1-4). In the eighth week a black, slimy deposit appeared and a strong smell of H_2S was given off. It seems likely that decomposition of organic matter in the samples resulted in the production of H_2S and a weak acid which was causing the dissolution of delicately constructed species. Deterioration of the assemblages continued progressively until the end of the 12 week period

when it was quite hard to identify the different species of Ellipsagelosphaera and Watznaueria because the distinguishing features were being obscured.

It can be concluded that samples which have been prepared by the method described in this paper should be mounted in a permanent slide and should have been examined under the scanning electron microscope within two weeks of their preparation. After two weeks the assemblages cannot be considered to be fully representative.

2.3. A review of alternative techniques

A survey of the literature shows that there are many alternative methods being used to extract and examine calcareous nannofossils. Although the literature survey presented here is not considered to be complete it illustrates the wide variety of techniques that are employed.

Firstly, many workers (BALDI-BEKE 1962; BRAMLETTE and SULLIVAN 1961; BUKRY 1969; EDWARDS 1963; MEDD 1971; MOSHKOVITZ and EHRLICH 1976) simply used water as the soaking agent. FORCHHEIMER (1972) used Hydrogen Peroxide (H_2O_2) and MOSHKOVITZ and EHRLICH (1976) described a method, used for samples in which the calcareous nannofossils are heavily masked by clay, which employs a combination of Potassium Hydroxide (KOH), boiling and Calgon. In her early work NOEL (1958) found that soaking marls in water for several hours was sufficient to break down the sediment but later (NOEL 1965) she described a method which used a solution of sodium bicarbonate as the soaking agent. She has also used Calgon for the preparation of some sediments (NOEL 1970).

There is a similarly wide variation in the techniques used for the separation of the calcareous nannofossils from the rest of the sediment. Some authors (BRAMLETTE and SULLIVAN 1961; BUKRY 1969;

GARTNER 1968; MEDD 1971; MOSHKOVITZ and EHRLICH 1976) isolated the calcareous nannofossils by allowing them to settle out of a suspension. FORCHHEIMER (1972) used filtration and NOEL (1965) employed elutriation, which is separation by suspending the particles in a current of water. The main alternative to the settling method is centrifuging (EDWARDS 1963; HAY 1965; MEDD 1971; MOSHKOVITZ and EHRLICH 1976; NOEL 1965, 1970). The "short centrifuging" method of EDWARDS (1963) has been used in a slightly modified form in this study. Other authors using centrifuging as a means of separating out the calcareous nannofossils made their own modifications to the speed of centrifuging. PIENNAAR (1966) considered the effects of centrifuging at different speeds. Also, a survey of the literature shows that while some authors retained both the supernatant liquid and the residue after centrifuging, others discarded the residue and retained the supernatant liquid and still others discarded the supernatant liquid while retaining the residue.

There is less variation in the methods used to mount the calcareous nannofossils on glass slides. Most authors seem to favour Canada Balsam as the mounting medium. STRADNER and PAPP (1961) suggested mounting the sample between two glass coverslips, rather than between a slide and a coverslip, so that oil immersion could be used to study both sides of specimens. BRAMLETTE AND SULLIVAN (1961) and EDWARDS (1963) proposed that mounting calcareous nannofossils in a viscous silicone medium would enable detailed examination of specimens in different orientations because they could be rolled over onto their sides by pushing the cover slips.

Very few of the workers who have recorded species abundance gave formal descriptions of how they obtained their measurement. MOSHKOVITZ and EHRLICH (1976) recorded the number of individuals of

each species in areas of a given size in a smear slide at a magnification of 1250x and calculated a mean value from several counts. Another method which can be employed is to record the number of specimens of each species in a count of 300 individuals. The author considers that this method cannot provide sufficiently detailed information about the composition of assemblages. HAY (1970) described a method whereby species abundance is recorded as a logarithm of abundance; this method has been employed by WISE and WIND (1976) and is used in this work. In publications where species abundance is shown in range charts but where no description is given about how the measurements were obtained, it must be assumed that these were achieved by estimate only. This is certainly a faster method than the formal ones described above but it has two major faults:

1. It cannot be used for correlatory purposes by more than one worker with any degree of reliability.
2. It is susceptible to human inconsistencies and could not be considered to be reliable in a study which was to continue for some length of time.

There is little variation in the methods used in the preparation of specimens for scanning electron microscopy since the procedure is firmly set by the operational requirements of the machine.

LAING (1974) pointed out that scanning electron microscopic examination of strew (scattered) mounts of palynological (or other micropalaeontological) material suffers from the drawback that it is virtually impossible to relocate any particular specimen for later study. He designed a grid which can be stuck onto the surface of a scanning electron microscope stub which enables relocation of specimens by means

of a series of coordinates. Although LAING's method was not tested in this study, the author suggests that the mesh of the grid would probably be too large to enable rapid relocation of calcareous nannofossils. For example, in one of LAING's squares ($500 \mu\text{m}^2$ approximately) one could find many calcareous nannofossils (size range: $\frac{1}{2} \mu\text{m} - 20 \mu\text{m}$). The method might, however, be of more value in palynology or in the study of larger calcareous microfossils. Also, in the study of calcareous nannofossils photographic negatives are regarded as being the original specimen so that relocation of specimens is seldom required.

THIERSTEIN, FRANZ and ROTH (1971) described a method for the study of a small object first with a scanning electron microscope and afterwards under a light microscope. Prior to this it had been very difficult to prove that a form described under the light microscope was the same as one seen in the scanning electron microscope because of the great difference in the resolution of the two microscopes. THIERSTEIN, FRANZ and ROTH used a corner of a rectangular cover slip instead of the usual circular stub cover glass. The dried suspension was coated with a very thin layer of metal so that the specimens could later be viewed in transmitted light. The authors suggested the use of a gold-palladium coating which appears green in transmitted light. The perpendicular edges of the cover slip were aligned parallel to the horizontal translation directions in both microscopes. Then the position of the specimen was described with reference to the x,y, translation directions and the corner of the cover glass which was taken as the fixed point. After study in the scanning electron microscope the specimens were mounted in Canada Balsam for light microscope examination.

This method has not been used in this study. Whilst it would have been satisfactory to have proved the identity of certain species under both microscopes, the procedure is not regarded as essential in view of the extent of the literature regarding the identification of species.

Following THIERSTEIN, FRANZ and ROTH (1971) another publication considered the problem of studying the same small specimen in light and electron microscopes. HANSEN, SCHMIDT and MIKKELSEN (1975) described a method for viewing the same nannofossil specimen under the light microscope, in the scanning electron microscope and then in the transmission electron microscope (LM-SEM-TEM). They also described how the same specimen can be viewed in the light microscope, the scanning electron microscope and then in the light microscope again (LM-SEM-LM). The value of this type of work was stressed by these authors who stated that "information is gained from one kind of microscope that amplifies and reinforces the observations seen in the other kind of microscope". They used a copper net with a "v" marked in the centre for their coordinate system. Since their method was not used in this study, there is little value in describing the full procedure here.

It suffices to say that any future work should certainly undertake to use the techniques of HANSEN, SCHMIDT and MIKKELSEN (1975), LAING (1974) and THIERSTEIN, FRANZ and ROTH (1971).

3. PORTUGAL

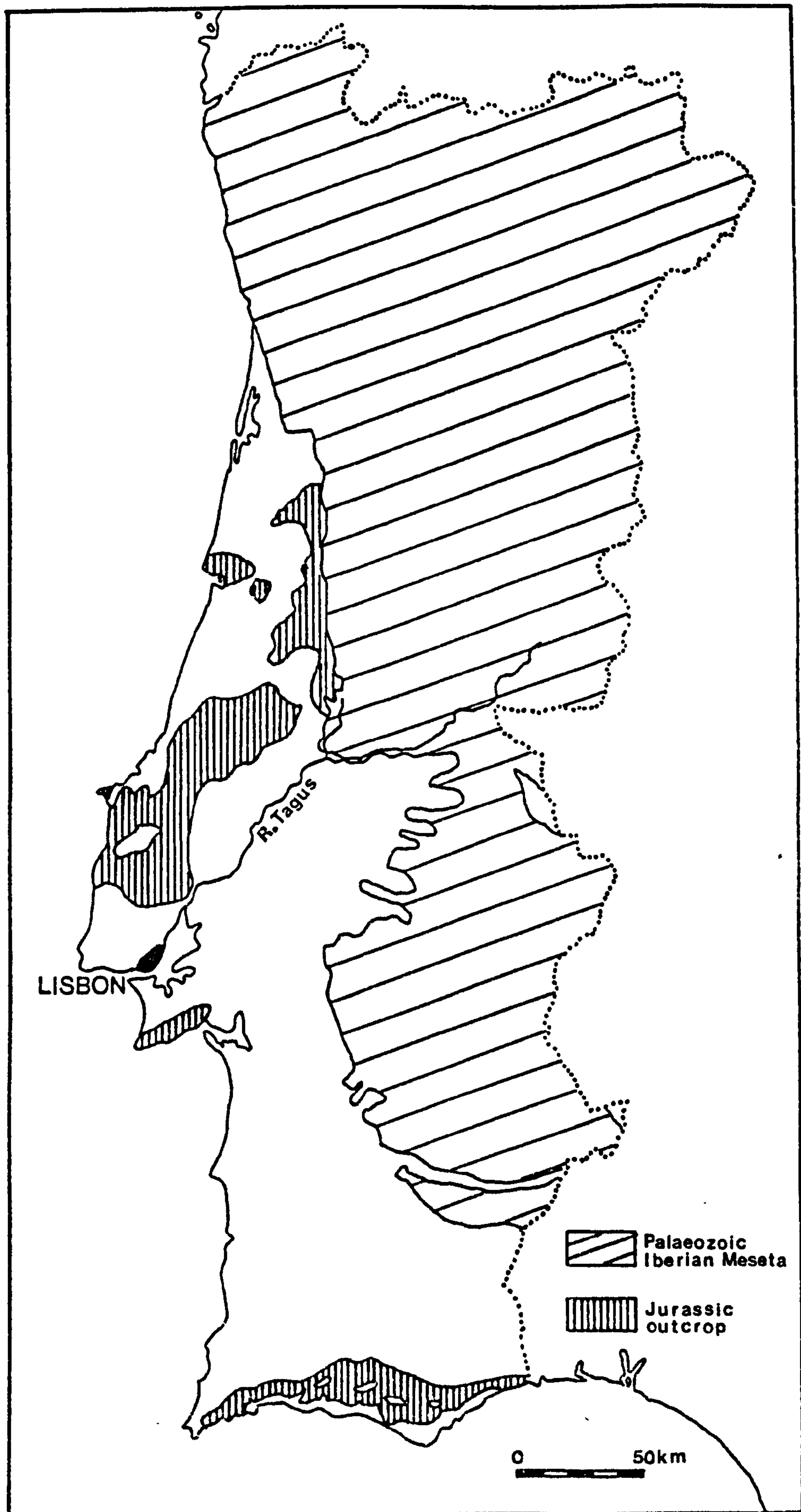
3.1. Introduction and review of previous work

In Portugal Jurassic rocks outcrop in a north-south coastal strip to the west of the crystalline, Palaeozoic Iberian Meseta and further south in an east-west coastal strip in Algarve. (See Text Fig. 4.)

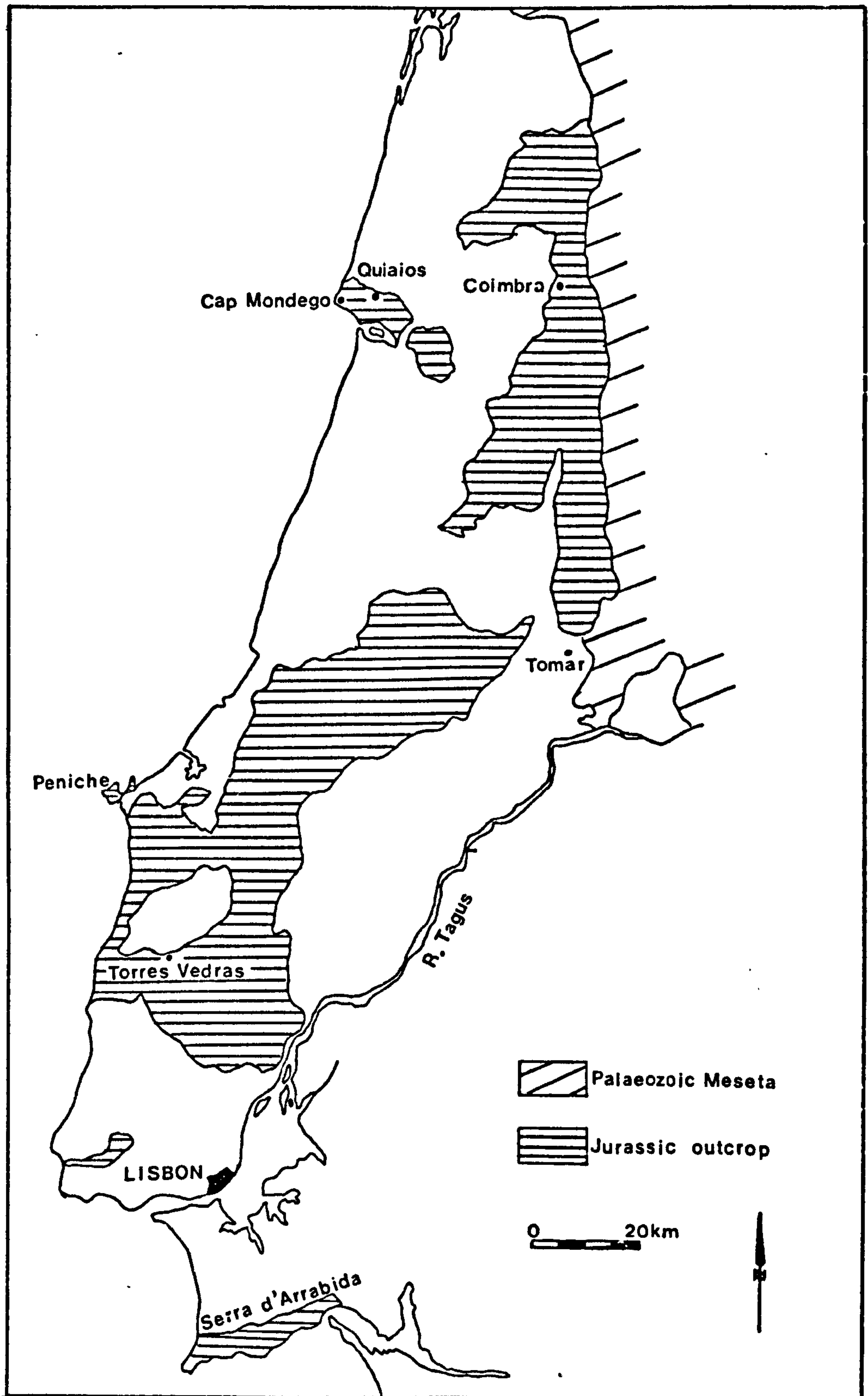
The history of work on the Jurassic of Portugal can be subdivided into three parts.

1. Pioneering work done in the first half of the 19th century
(LINK 1801; ESCHWEGE 1831, 1837; COLLEGNO 1850; SHARPE 1850).
2. A second phase marked by the considerable contribution of
CHOFFAT (1880, 1885, 1887, 1893, 1894, 1900, 1904, 1908, 1909
and with KOBAYASHI 1904) who almost single handed described the
essential stratigraphy and palaeontology of Portugal.
3. The present period which has seen the publication of much work
(ARKELL 1956; DOUBINGER, ADLOFF and PALAIN 1970; ELMI et al
1969; FRANCA et al 1964; GEYER 1955; MEMPEL 1955; MOUTERDE 1947,
1951, 1953a, 1953b, 1955, 1965, 1967, 1970; MOUTERDE et al 1971;
MOUTERDE, ROCHA and RUGET 1971; PALAIN 1968a, 1968b, 1970;
RAMALHO 1970, 1971; RAMALHO and REY 1969, 1975; RENZ 1912; REY
et al 1968; RUGET-PERROT 1961; SCHOTT and STAESCHE 1957;
TINTANT 1967a, 1967b; ZBYSZEWSKI 1943).

As the maps in Text Figs. 4 and 5 illustrate, the main Jurassic outcrop lies to the north of the River Tagus. During the Jurassic this area formed one of three sedimentary basins which were open to the west towards the ocean that predated the present Atlantic. The deposits show a generally marine, rhythmic sedimentation of marls and limestones



Text Fig. 4 Jurassic Outcrop in Portugal.



Text Fig.5 Detailed Distribution of Jurassic Outcrop in the Coastal Strip.

and contain a fauna which shows strong affinities with that of western Europe (MOUTERDE et al 1971). To the south of the River Tagus, but still in the north-south coastal strip, the Jurassic outcrops in the Serra d'Arrabida; this area occupies the second of the three sedimentary basins. (See Text Fig. 5.) Here deposition was more variable and the facies show both continental and marine influences. MOUTERDE et al (1971) suggested that the sediments indicate the presence of an emerging area to the south of Arrabida which separates the northern basins from the third sedimentary basin in the south, the Algarve basin. This basin is quite distinct from the others, both in its sedimentary facies, which consists of thick sequences of limestones and dolomites and in its fauna which MOUTERDE et al suggest has clearly "Mesogeen" characteristics. (The author has not been able to find a translation of the term "Mesogeen" but assumes that it denotes a southern, Tethyan or Mediterranean influence.)

Sampling by Professor T. Barnard and some of his students during 1964 and 1969 was restricted to the area north of the River Tagus where the Jurassic outcrop is greatest.

3.2. The general Jurassic geology of the northern sedimentary basin

A brief outline of the geological history of this area will place the sampled sections in a wider palaeogeographic perspective.

In this northern basin the Hettangian, which consists mainly of sandstones and dolomites and the Lower Sinemurian, which is in dolomites and dolomitic limestones, are not well known. This is presumably because fossils which permit refined biostratigraphy are seldom preserved in such hard rocks.

In the fossiliferous limestones and marls which overlie the

Lower Sinemurian geologists have identified the obtusum-raricostatum Zones of the Upper Sinemurian. A continuation of the fossiliferous marl and limestone facies into the Pliensbachian allows subdivision of this stage into a lower part, the Carixian (jamesoni, ibex, and davoei Zones) and an upper part, the Domerian (margaritatus and spinatum Zones). Throughout this part of the Jurassic the deposits diminish in thickness and become more calcareous from the north towards the south and from the west towards the east.

The sedimentation in the Toarcian is slightly more variable although it is still essentially interbedding of limestones and marls. MOUIERDE et al (1971) noted that the thickness of the Toarcian is very great in the region of Coimbra (300 m) but diminishes towards the west (200 m in Quiaios) and towards the south (70 m at Tomar) where limestones dominate the lithology. In the latter sediments brachiopods are common while ammonites are more rare. In the Upper Toarcian at Peniche grains of quartz in the limestones are thought to suggest close proximity to an emerging crystalline region.

The Bajocian in Portugal is complete and is largely fossiliferous. Limestones and marls again dominate the lithology. RUGET-PERROT (1961) described the detailed succession of ammonites which conforms with that known in western Europe. The facies change in a similar manner to those in the Lower Jurassic and RUGET-PERROT suggested that shallow water conditions prevailed everywhere.

The Bathonian in the area north of the River Tagus is best represented by marls and limestones at Cap Mondego where the ammonite fauna enabled RUGET-PERROT to identify lower, middle and upper subdivisions of the stage. The area of marl and limestone deposition seems to have been restricted to Cap Mondego; elsewhere limestones

dominate. The marly facies was more widespread in the Callovian than it had been in the Bathonian.

In the northern basin signs of a marine regression are found from Middle Callovian time and RUGET-PERROT stated that the regression seems to be complete by the end of the stage. MOUTERDE et al (1971) noted that there is an important break in sedimentation from the middle of the Upper Callovian to the Middle Oxfordian which corresponds to the period of regression during which some erosion occurred.

The Upper Jurassic is well represented at Torres Vedras where it was the subject of the classic study of CHOFFAT (1893). He noted a great variety of facies of continental, lacustrine and marine types and he grouped all the strata between the Upper Callovian and "le Pterocerien" under a new stage name, the Lusitanian. CHOFFAT in KOBY and CHOFFAT (1904) recognised the purely local value of his Lusitanian stage and he did not even consider it to be applicable in Algarve.

The term was brought into more general use when HAUG (1910) redefined it. RUGET-PERROT (1961) re-examined the sections of CHOFFAT and retained the term Lusitanian; she did, however, lower the upper boundary of the stage since the uppermost beds of CHOFFAT's Lusitanian stage were found to contain a typically Lower Kimmeridgian ammonite fauna. FRANCA et al (1964) also conserved the stage name Lusitanian and defined its limits as from the Argovian to the boundary between the Lower and Middle Kimmeridgian of ARKELL. MOUTERDE (1971) recalled that the Lusitanian stage was created to include a wide variety of facies ranging from continental to marine types of Upper Callovian to Kimmeridgian age. MOUTERDE et al (1971) considered that the Lusitanian probably overlaps the Oxfordian and Kimmeridgian stages of d'ORBIGNY. They rejected the term on the grounds of its purely local value and

described the Portuguese Jurassic in terms of the better known Oxfordian, Kimmeridgian and Portlandian stages. An attempt has been made to summarise the very confused state of present opinion on this matter in Text Fig. 6.

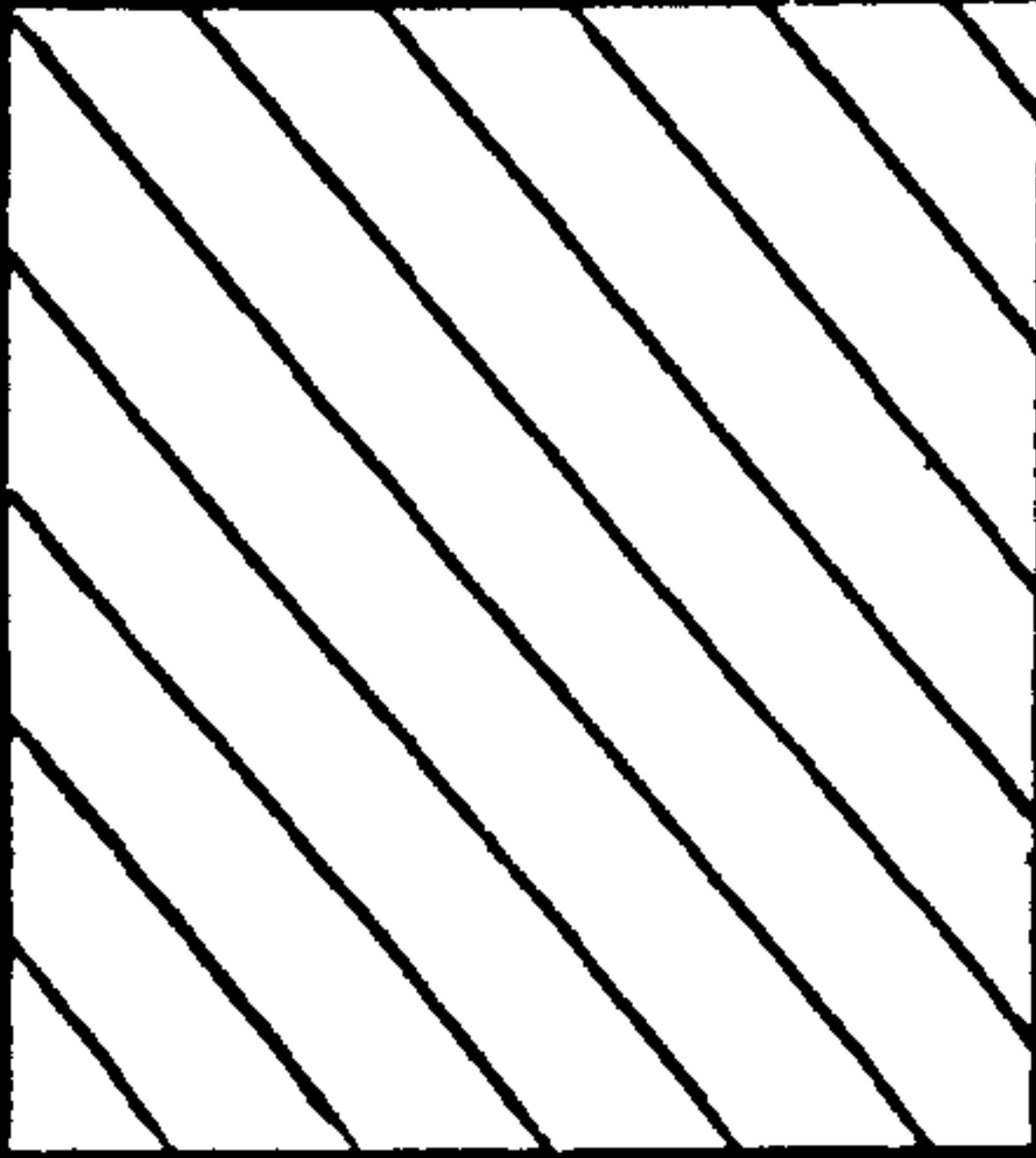
During the Kimmeridgian and Portlandian the sea is thought to have retreated again. At this time lagoonal and lacustrine deposits were laid down with some marly limestones. In the Portlandian and during the passage from the Jurassic to the Cretaceous marine deposition was only preserved in the area of Sintra which lies just west of Lisbon.

3.3. The sampled localities

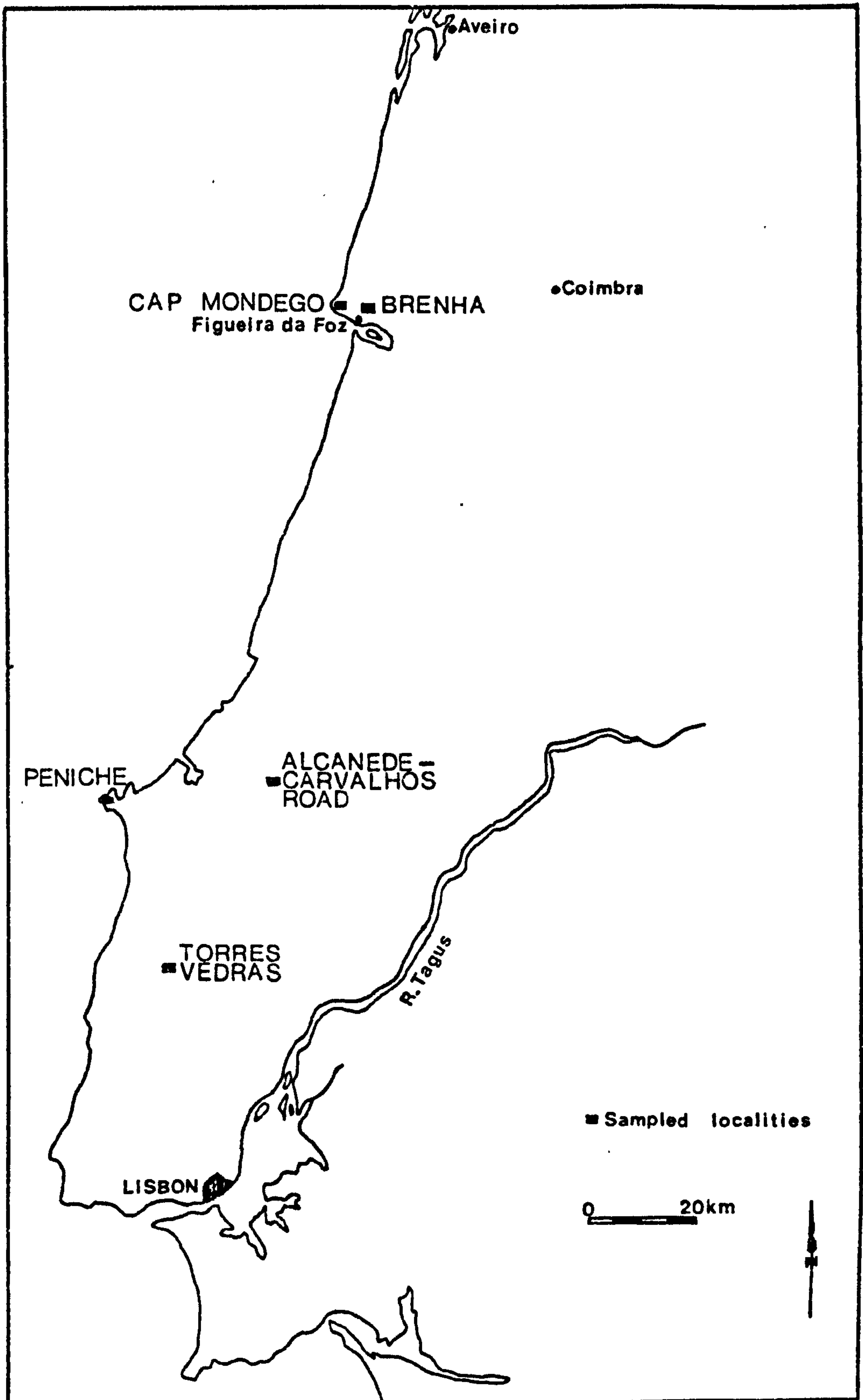
With this brief outline of the geological history of the northern sedimentary basin in mind, the sampled sections can now be considered. It should be noted that, since the author was not present on either of the two sample collecting trips, information concerning the sample localities and the sections is gathered from that available in the field notebooks and in the relevant literature.

Five localities were selected to give a good coverage of the Lower and Middle Jurassic of the area and some insight into the more limited sedimentation in the Upper Jurassic of Portugal. These are located in Text Fig. 7.

An almost complete section in marine sediments from the Lower Sinemurian to the top of the Bathonian was collected along the Brenha Road Section on the road between Figueira da Foz and Aveiro at Brenha. It was the lower part of this section which was described previously by the author (HAMILTON 1977). Two other Middle Jurassic sections were sampled at Cap Mondego, which lies on the coast to the west of Brenha. Moving further south in the basin, an Upper Jurassic section was

ARKELL	d'ORBIGNY	HAUG	CHOFFAT	RUGET-PERROT	FRANCA et al (1964)
KIMMERIDGIAN	KIMMERIDGIAN	KIMMERIDGIAN		KIMMERIDGIAN	KIMMERIDGIAN
		Virgulian	Couches d'Abadia	LUSITANIAN	LUSITANIAN
		Pteroceran			
		LUSITANIAN	Couches de Montejunto	LUSITANIAN	LUSITANIAN
	CORALLIAN	Sequanian	Couches de Cabaco	LUSITANIAN	LUSITANIAN
		Rauracian			
		Argovian			
	OXFORDIAN				
OXFORDIAN	OXFORDIAN	OXFORDIAN	OXFORDIAN	OXFORDIAN	OXFORDIAN

Text Fig.6 Definition of the Lusitanian Stage.



Text Fig. 7 Sampled Localities in Portugal.

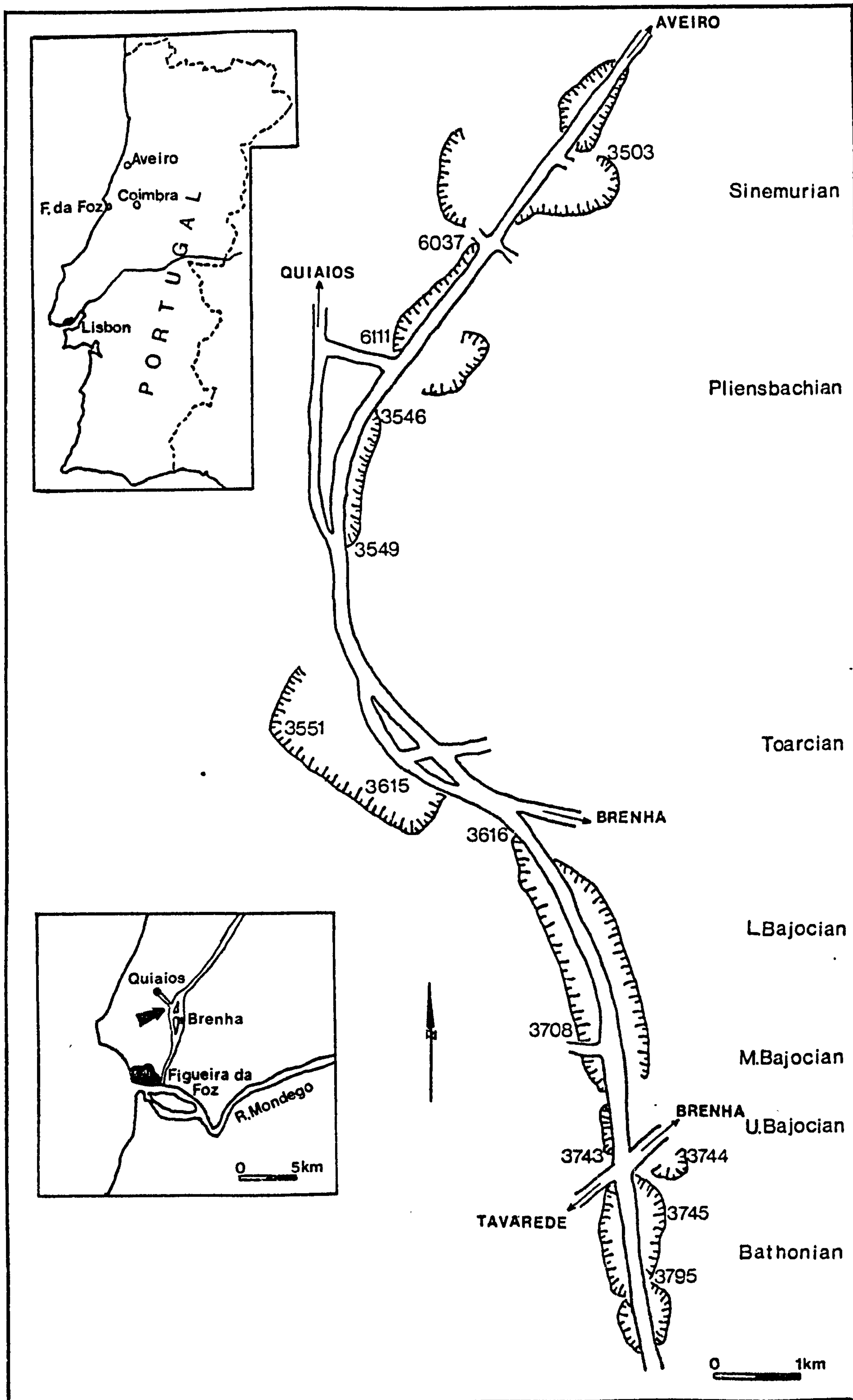
sampled on the road from Alcanede to Carvalhos and a short section in the Lias was collected on the Peniche Peninsula. Finally, a second Upper Jurassic section was sampled in the Torres Vedras area.

3.3.1. The Brenha Road Section

This section, whose location and stratigraphy is shown in Text Fig. 8, is found in a new road cutting on the road between Figueira da Foz and Aveiro to the west of the village of Brenha. SCHOTT and STAESCHE (1957) gave a detailed description of a section along the old Figueira da Foz - Aveiro road which ran through Brenha. They demonstrated that a complete section from the Sinemurian into the Lower Lusitanian can be found in the Brenha area. For this study no Callovian or Lusitanian material was collected because at Brenha this interval is largely represented by non-marine and paralic deposits.

Detailed description of the lithology of the Lias part of the section is given in HAMILTON (1977). The Middle Jurassic interval consists of a series of alternating limestones and marls. The Lower Bajocian is an interbedded series of thin shale, marl and limestone bands. In the Middle Bajocian the limestone is more massive and the Upper Bajocian, which outcrops to the south of the Tavadede to Brenha road junction, is in massive blue hydraulic limestones interbedded with cross-bedded silty limestones. The Lower Bathonian consists of grey hydraulic limestones alternating with beds of siltstone, some of which show cross bedding. In the Upper Bathonian light grey shales with thin bands of silty limestone are dominant.

The sampling of the Brenha Road Section was done with reference to ammonites which were collected and identified at the time of sampling by Dr. J.H. Callomon. In the Lias he was able to define the boundary



Text Fig. 8 The Brenha Road Section : Location and Sample Distribution.

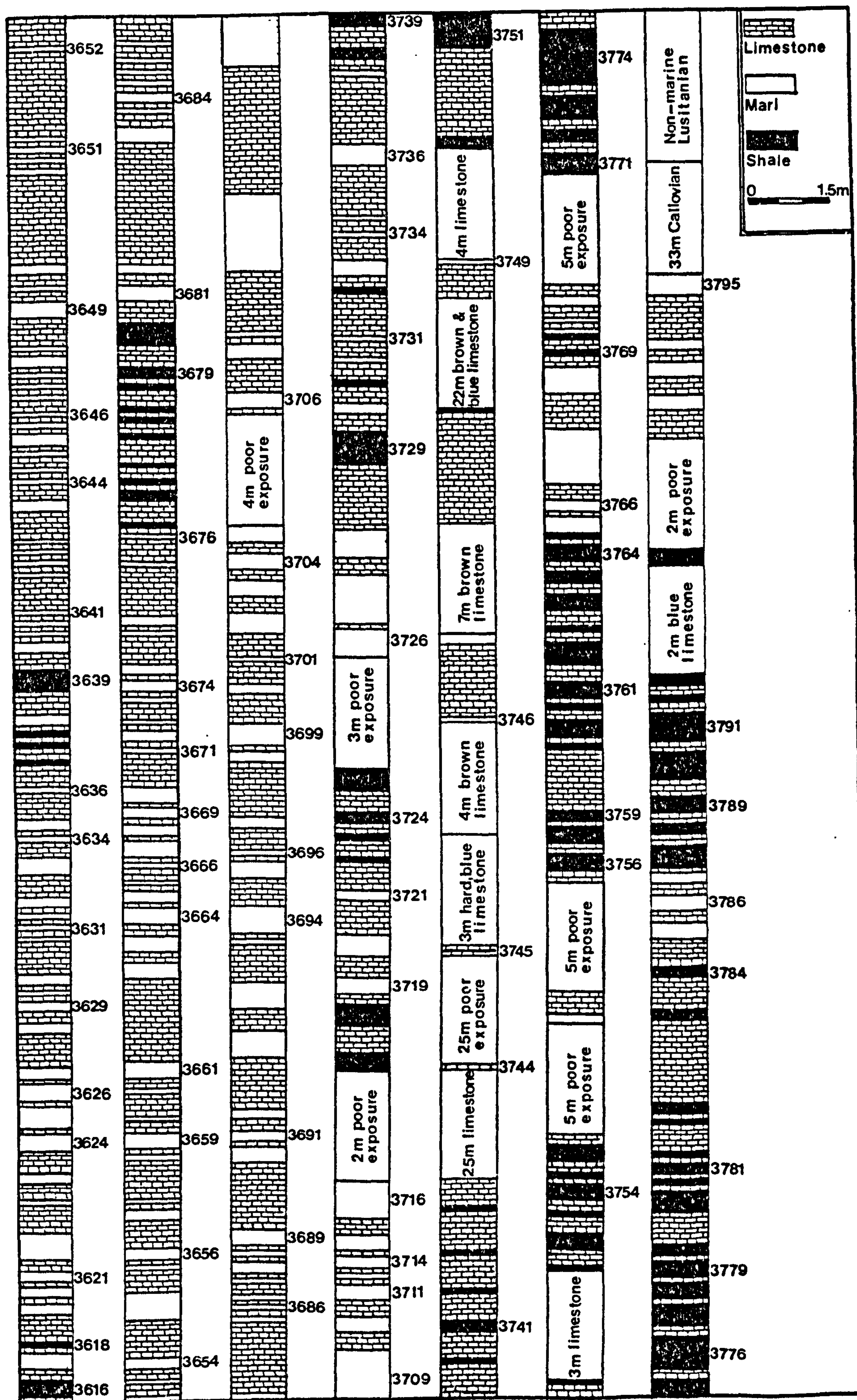
between the Lower and Upper Sinemurian and identify all the classic ammonite zones for the Pliensbachian. He also identified one ammonite zone in the Toarcian (bifrons Zone) and was able to define the limits of this stage. Ammonites collected along the Middle Jurassic part of the Brenha Road Section did not provide such good biostratigraphic information. In fact, no formal ammonite zones were defined for this interval, the ammonites being used only to subdivide the Bajocian and Bathonian stages. The location of the samples in the section and the lithology are illustrated in Text Fig. 9.

A discussion on the calcareous nannofossil assemblages from the Lower Jurassic part of the Brenha Road Section is given in HAMILTON (1977). The samples from the Middle Jurassic interval yielded assemblages which contained a good abundance of calcareous nannofossils. The preservation of the specimens was not very good; many of the robust forms showed signs of calcium carbonate overgrowth and some of the more delicate forms were affected by dissolution processes. However, the alteration of the specimens was not sufficient to obscure the structural details and so prevent identification.

The abundance of the species and their stratigraphic ranges are given in Text Fig. 10. The Lower Jurassic part of the section is included in this figure since it is useful to record the most complete species ranges available and it is interesting to examine the changes in assemblages with time.

It is clear that there are several species which are long ranging forms. The following species are recorded from the bottom of the section in the Lower Sinemurian to the top of the section at the top of the Bathonian.

Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975



Text Fig.9 The Brenha Road Section: Lithology and Sample Distribution.

Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968

Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938

Staurorhabdus quadriarcullus (NOEL 1965) NOEL 1973

Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971

Also, Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 ranges from the Lower Sinemurian to the Middle Bajocian and Podorhabdus cylindratus NOEL 1965 is found from the Lower Pliensbachian to the top of the section.

It is equally clear that the assemblages are normally dominated by a few species. For example, Discorhabdus ignotus and Schizosphaerella punctulata are dominant throughout the Lower and Middle Jurassic and Discorhabdus sp., Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968 and Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 are important constituents in Middle Jurassic assemblages.

Apart from these long ranging and dominant forms there are a few biostratigraphically useful species. Most notable in this group are specimens of the genus Stephanolithion which first appear at the bottom of the Bathonian. Their wheel-like structure makes them easy to identify in both light and scanning electron microscopes. Other biostratigraphically useful species include

Cretarhabdus sp. 1

Cretarhabdus sp. 2

Ellipsagelosphaera crucicentralis MEDD 1971

Hexapodorhabdus cuvillieri NOEL 1965

Finally, the range chart shows that within the Lower and Middle Jurassic in the Brenha Road area there are three distinct phases marked by the introduction of new species. The first phase, in the Middle and Upper Toarcian, is discussed in HAMILTON (1977). The second phase which

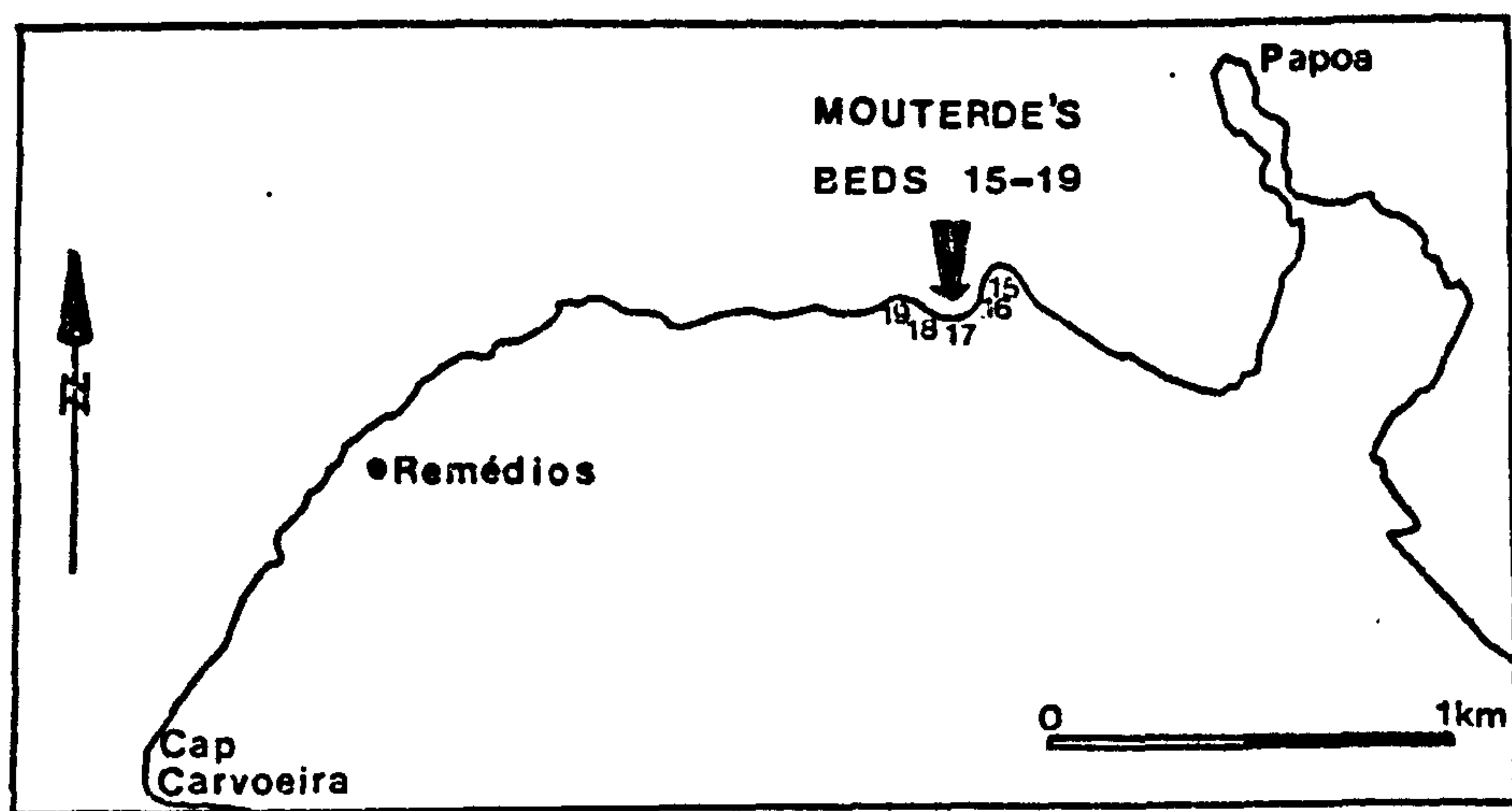
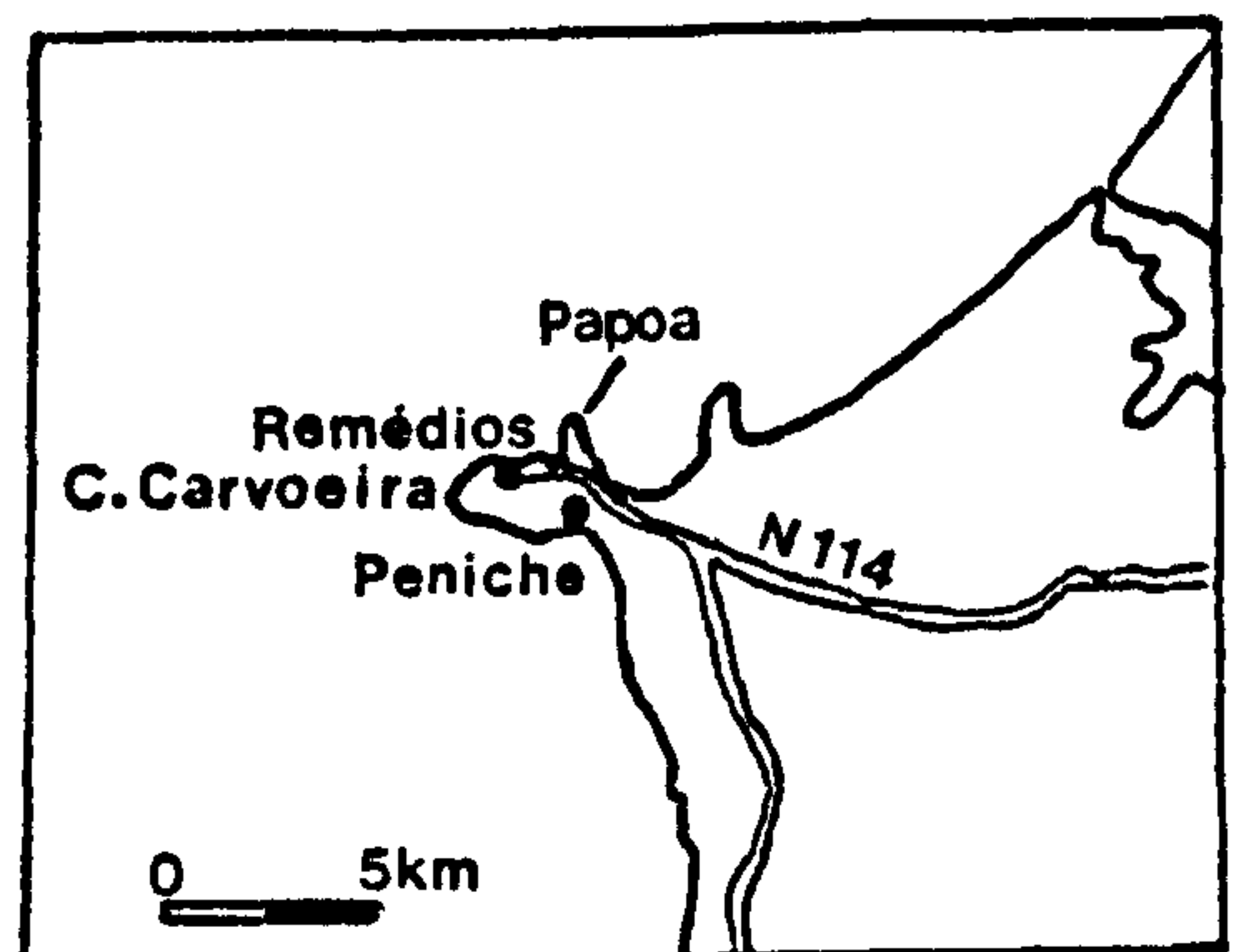
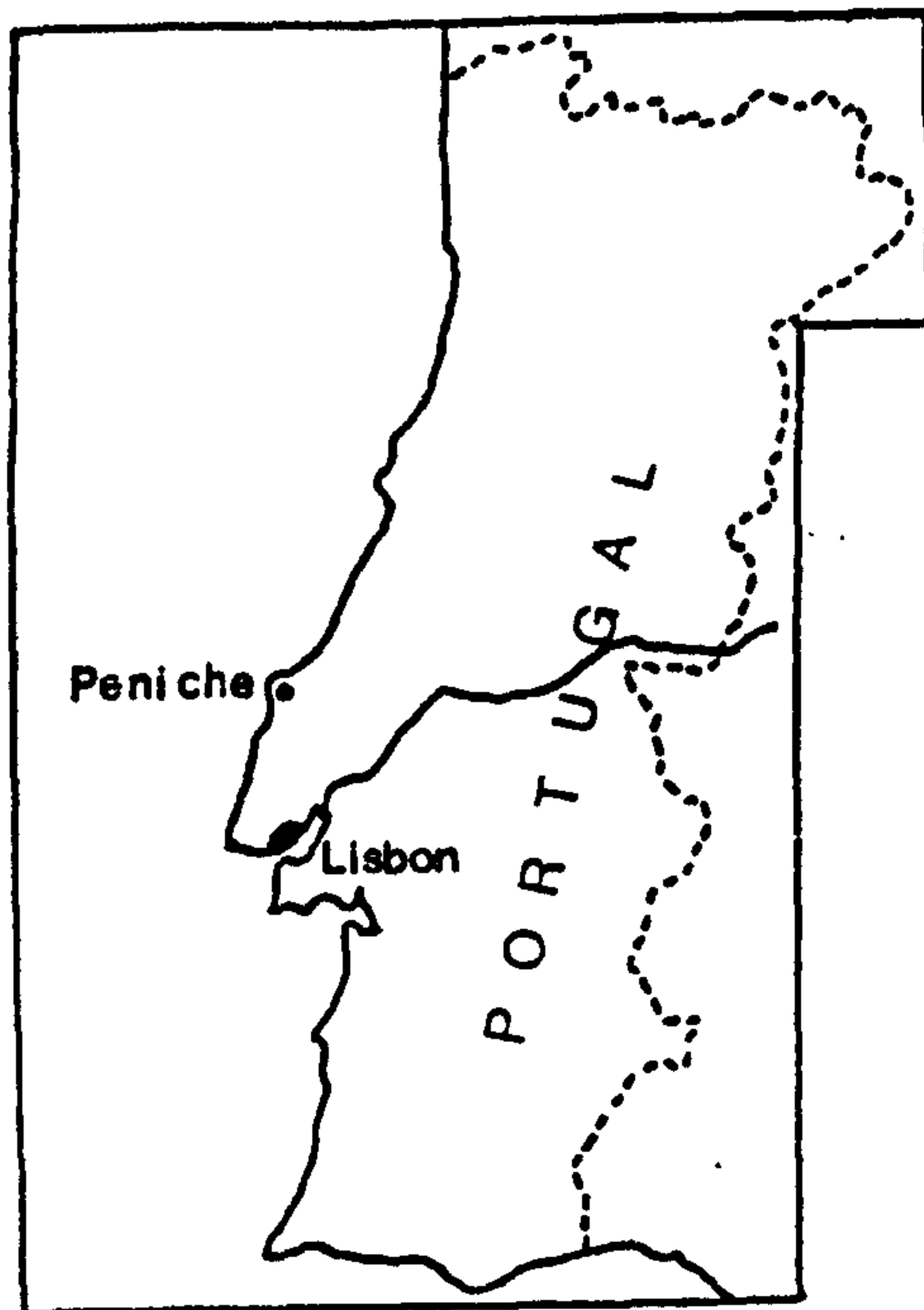
sees the appearance of Ellipsagelosphaera keftalrempti, Hexapodorhabdus cuvillieri and Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968, is more diffuse and spans over most of the Lower Bajocian. The third phase, at the beginning of the Bathonian is strongly defined by the appearance of Stephanolithion hexum ROOD & BARNARD 1972, Stephanolithion speciosum DEFLANDRE 1954 and Stephanolithion speciosum var. octum ROOD & BARNARD 1972.

Finally, it is notable that the number of species recorded in the assemblages doubles during the Lower to Middle Jurassic interval. (12 species are found at the bottom of the section while 24 is the maximum number recorded in the Bathonian.)

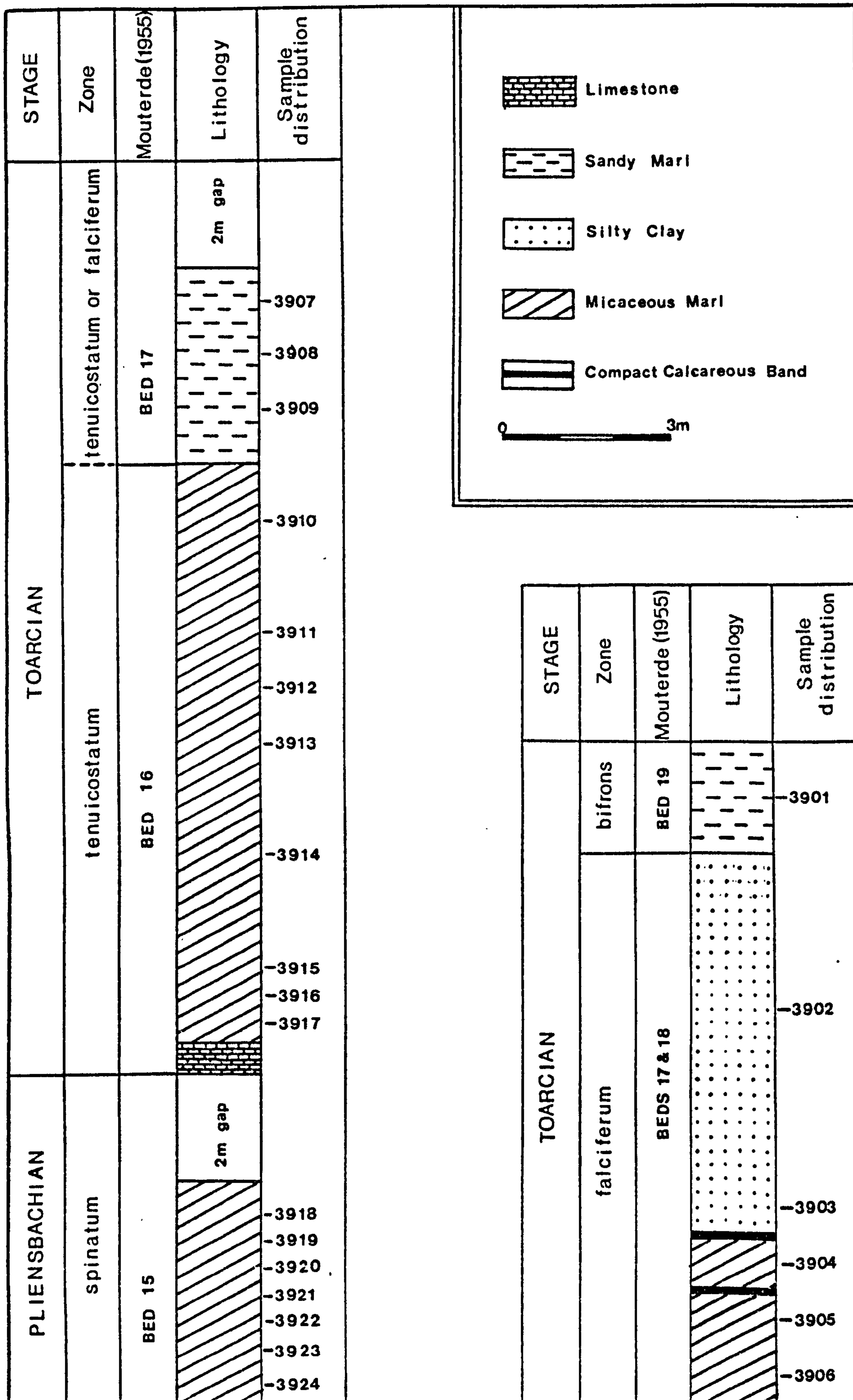
3.3.2. The Peniche Section

The geology of the Peniche Peninsula was first described in detail by CHOFFAT (1880). More recently, MOUTERDE (1955) gave a detailed lithological and palaeontological description of the whole of the Lias at Peniche. The sample collection by Professor T. Barnard in 1969 was made with reference to the section described by MOUTERDE. The age assignments and bed nomenclature as used by MOUTERDE are applied in this study. Although the whole of the Lias is exposed here, only a short section of Upper Pliensbachian and Toarcian age was collected for this study. The Peniche Section is located in Text Fig. 11 and the lithology, sample distribution and bed nomenclature of MOUTERDE are illustrated in Text Fig. 12.

The Upper Pliensbachian part of the section is formed mainly of micaceous, pyritised marls which are light grey in colour. The lowermost Toarcian beds are in similar light grey micaceous marls with some narrow bands of compacted, calcite rich marl interspersed in them. The



Text Fig.11 The Peniche Section : Location.



grey micaceous marls become more sandy in MOUTERDE's Beds 17 and 18 and are often yellowish brown in colour. MOUTERDE noted that the increase in the amount of mica fragments and other detritus together with an increase in the sand content of the sediment, both of which are recorded in the Toarcian at Peniche, suggests that more littoral conditions prevailed in the area at the time.

The samples from this section produced fairly well preserved assemblages of calcareous nannofossils whose stratigraphic distributions are shown in Text Fig. 13. The assemblages are dominated by Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968 and Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938. Samples 3924 to 3913 contain some typically Lower Lias species such as

Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973 and

Parhabdololithus sp.

Samples 3911 to 3901, on the other hand, contain

Carinolithus superbus (DEFLANDRE 1954) PRINS 1969,

Discorhabdus patulus (DEFLANDRE 1954) NOEL 1965,

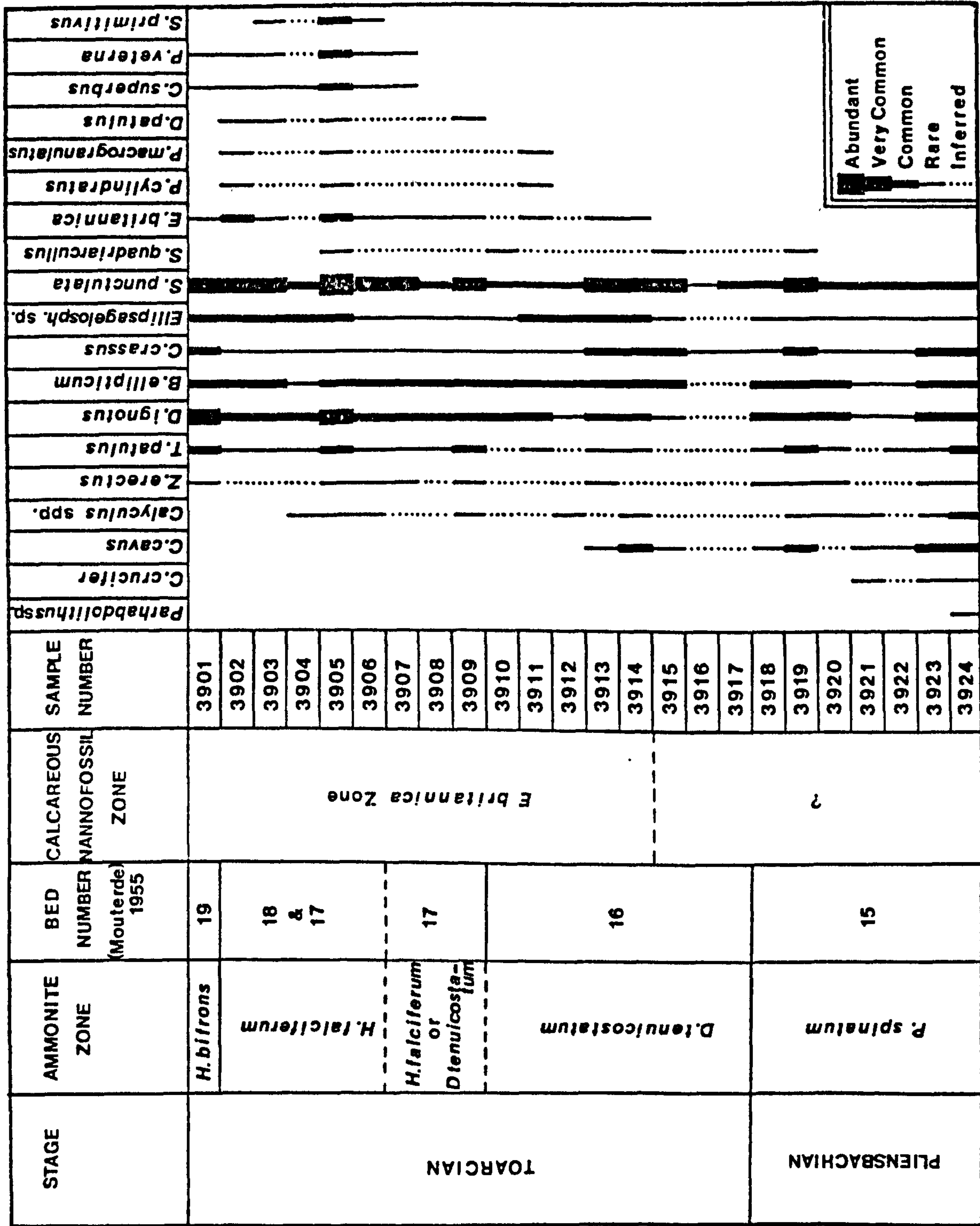
Podorhabdus macrogranulatus PRINS 1969 ex ROOD, HAY & BARNARD 1973 and

Striatomarginis primitivus ROOD, HAY & BARNARD 1973,

species which are better known in the Toarcian and Bajocian. The range chart (Text Fig. 13) also includes a species Ellipsagelosphaera sp.

which is applied to very small specimens of the genus Ellipsagelosphaera which cannot be defined at species level because of their small size.

It seems possible that they are the ancestral forms of Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968 which is here found in samples 3918 - 3901.



Text Fig. 13 Stratigraphic Distribution of Calcareous Nannofossils in the Peniche Section.

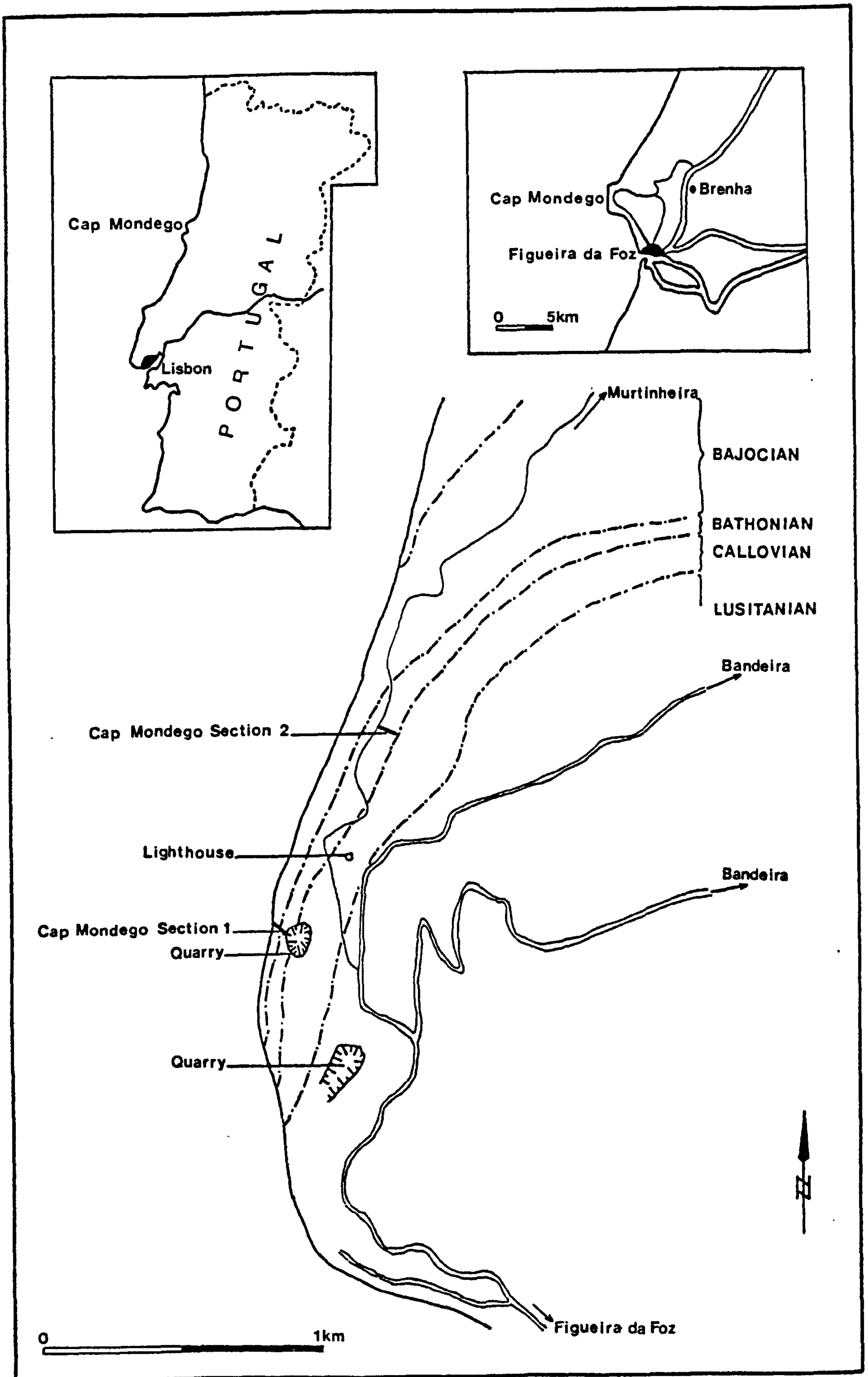
3.3.3. The Cap Mondego Sections

To the north of the River Mondego and west of Figueira da Foz the Jurassic is exposed in a coastal section at Cap Mondego and in two quarries a short distance inland. The area was described in great detail by RUGET-PERROT (1961) and the sampling by Professor T. Barnard for this study was done with reference to this publication.

The sketch maps in Text Fig. 14, taken partly from RUGET-PERROT, show that sediments of Bajocian to Lusitanian age are exposed in this area. RUGET-PERROT noted that the series at Cap Mondego is well exposed, very fossiliferous and has a thickness of 380 m, excluding Lusitanian deposits. She was able to identify all the standard ammonite zones of North-west Europe in the Bajocian and Bathonian stages. The Callovian fauna, on the contrary, differed slightly from that normal in North-west Europe and RUGET-PERROT recorded a Mediterranean influence. She noted a break in the succession, corresponding perhaps with a period of non-deposition or erosion associated with the Callovian/Oxfordian regression which affected the area. After this fresh water and lagoonal deposits of Lusitanian age were recorded.

Sediments of Bajocian and Bathonian age are found in the coastal strip at Cap Mondego which consists of fairly steep cliffs whose sparse vegetation cover ensures good exposure of the sediment. The beds dip at an angle of between 30° - 60° towards the south-east. Deposits of Callovian age are exposed in the northern of the two quarries while the southern quarry contains exposures of Lusitanian age.

The first and longest section (Cap Mondego Section 1), located in Text Fig. 14, was taken from the shoreline, in sediment of supposed Middle or Upper Bajocian age (RUGET-PERROT 1961, Fig. 4), into the first quarry where Callovian deposits were collected. The lithology and sample



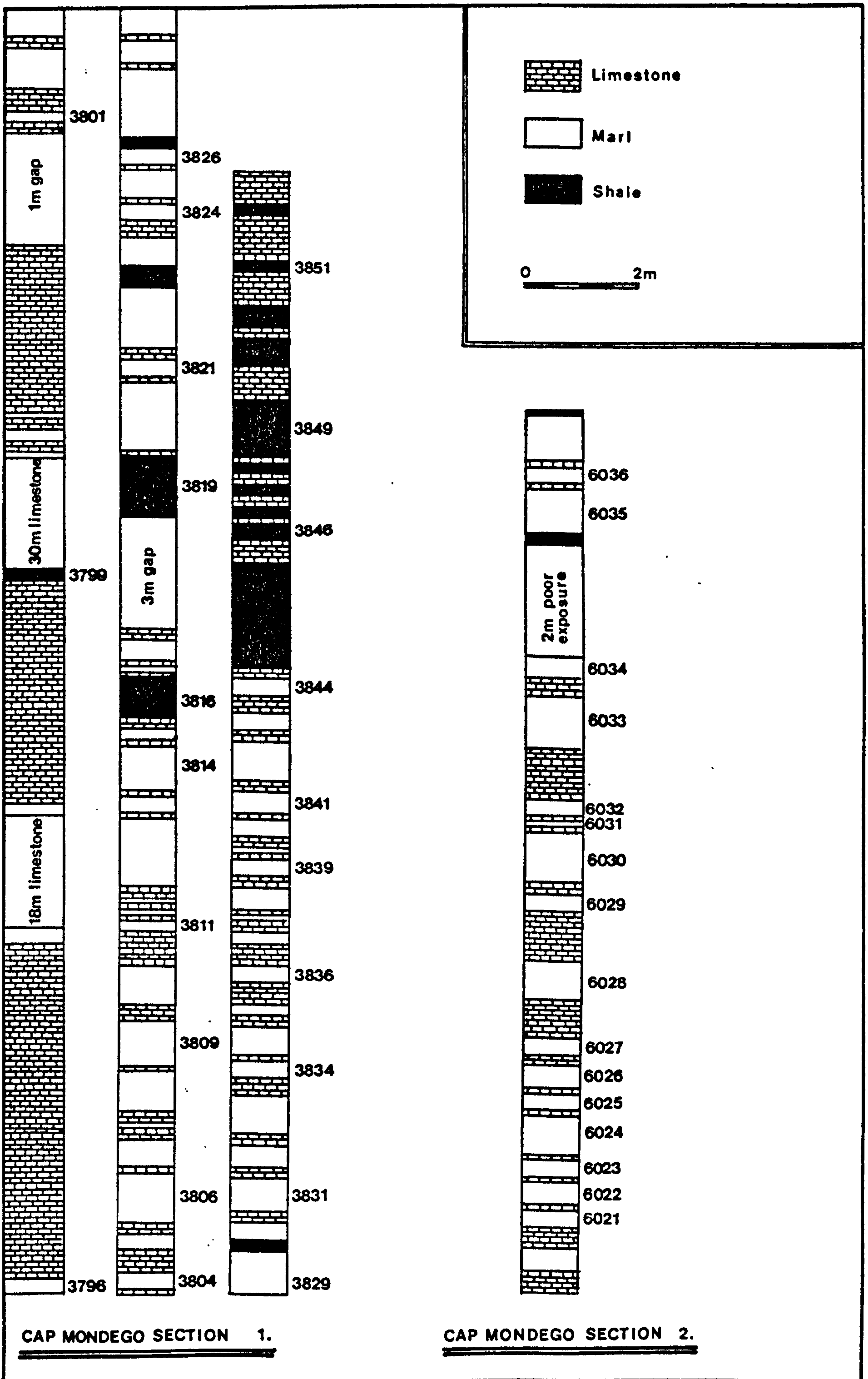
Text Fig. 14 The Cap Mondego Sections: Location.

distribution for this section are shown in Text Fig. 15. In addition, three samples of Lusitanian age were collected in the southern quarry.

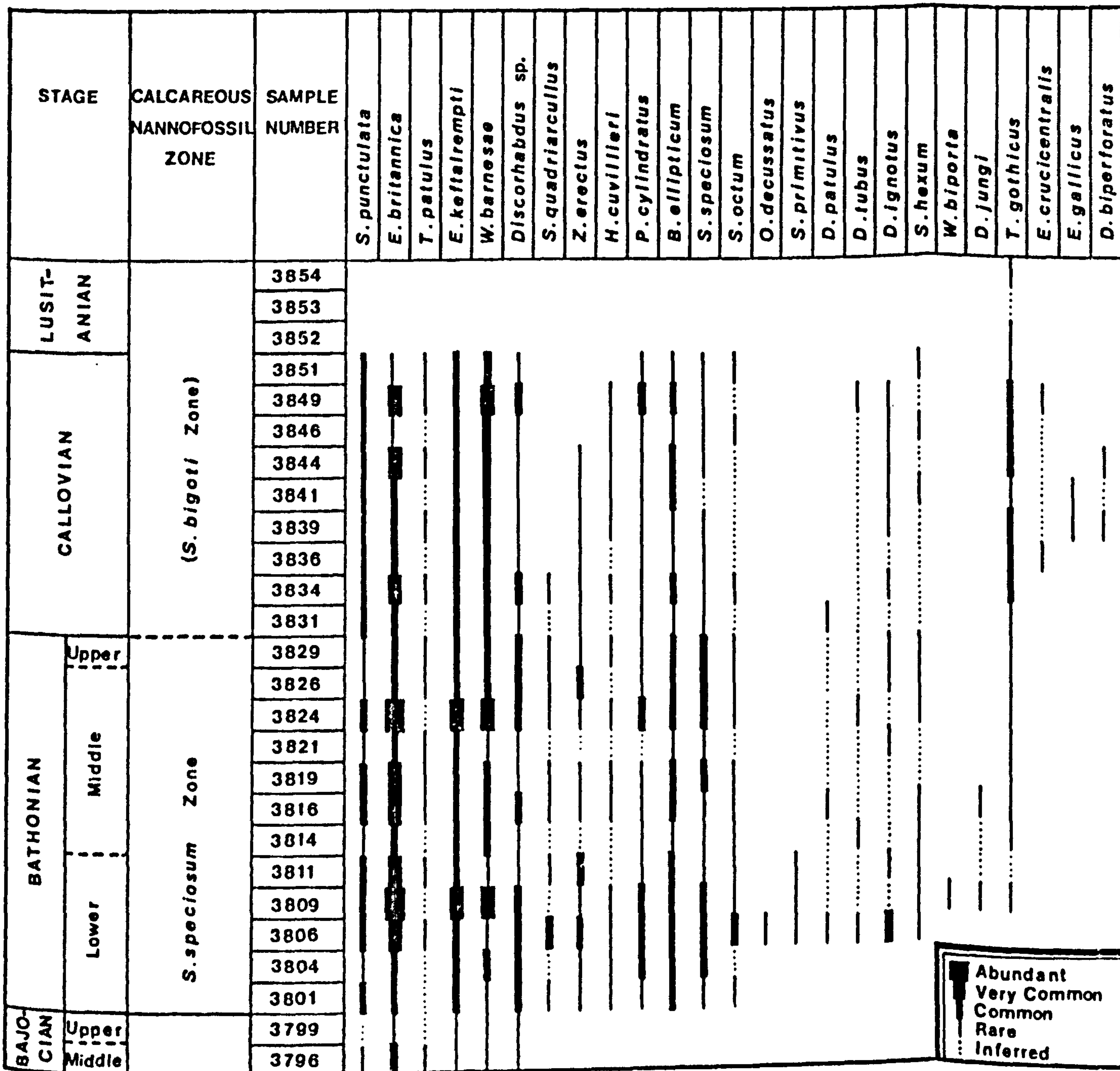
The precise location of the second and shorter section (Cap Mondego Section 2) was not recorded in the field notebook. The section was described as being in Bathonian sediments and on the east side of the road or track which leads to Murtinheira. The probable position of the section has been tentatively marked on the location map in Text Fig. 14. The lithology and sample distribution for this section are also given in Text Fig. 15.

The stratigraphic subdivision assigned to the Cap Mondego Section 1 and illustrated in the range chart in Text Fig. 16 is tentative. Teloceras blagdeni, the index ammonite for the top of the Middle Bajocian, was recorded at the base of the section. No other ammonite locations were recorded in the field notebook but, using ammonites, Dr. J.H. Callomon was able to define the Lower, Middle and Upper divisions of the Bathonian stage and the Bathonian/Callovian boundary in the northern quarry.

The Bajocian-Callovian samples from the Cap Mondego Section 1 produced a good abundance of calcareous nannofossils whose stratigraphic ranges are given in Text Fig. 16. The preservation of the specimens was not very good and many of them showed signs of overgrowth. The assemblages are dominated by Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968, Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 and Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968. The appearance at the base of the Bathonian of Stephanolithion hexum ROOD & BARNARD 1972, Stephanolithion speciosum DEFLANDRE 1954 and Stephanolithion speciosum var. octum ROOD & BARNARD 1972 is biostratigraphically important.



Text Fig.15 The Cap Mondego Sections: Lithology and Sample Distribution.

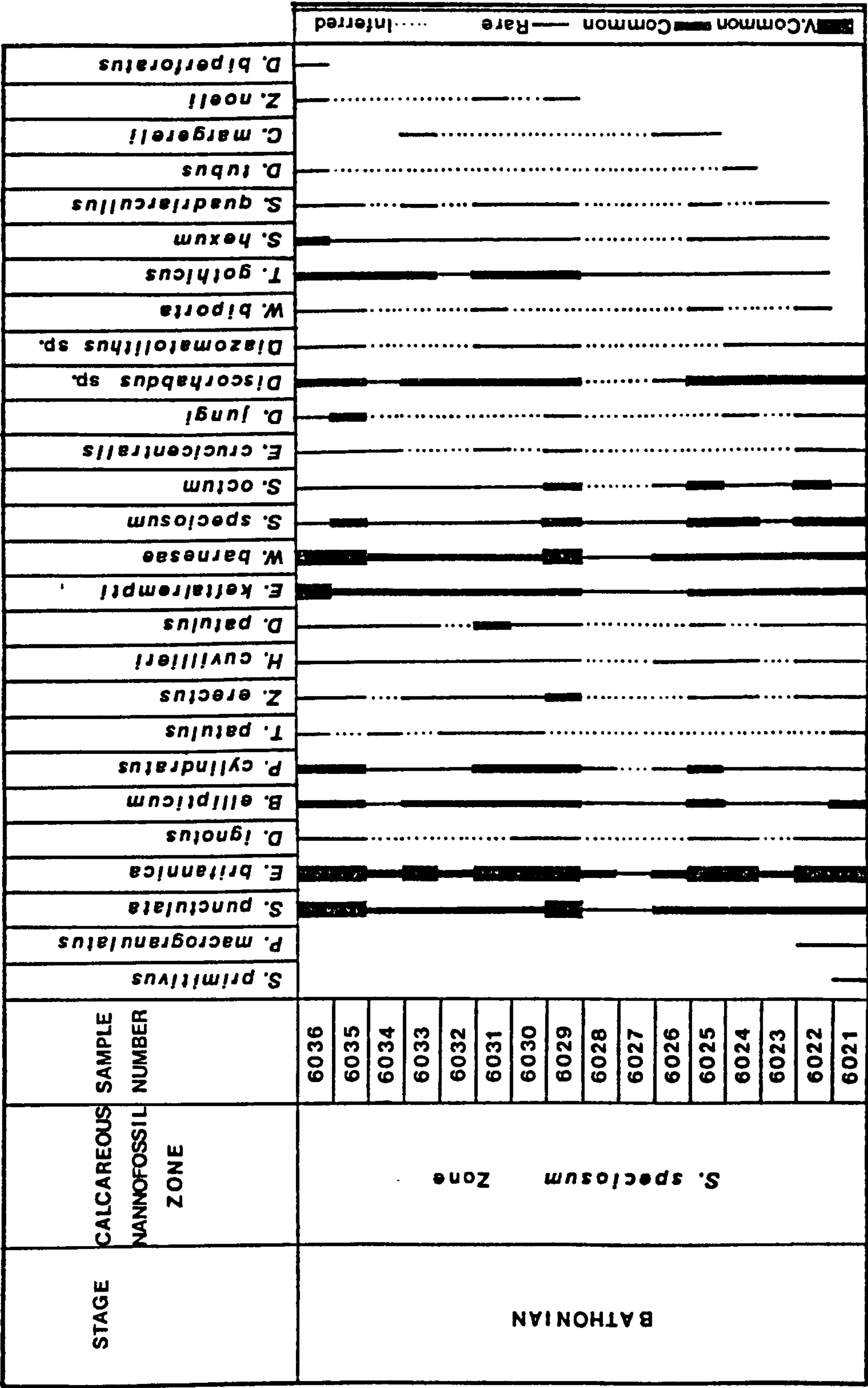


Text Fig. 16 Stratigraphic Distribution of Calcareous Nannofossils in the Cap Mondego Section 1.

Analysis of the three Lusitanian samples from the southern of the two quarries revealed that sample 3853 was barren while samples 3852 and 3854 contained one species, Tetralithus gothicus DEFLANDRE 1959. This species first appears in the Lower Bathonian in the Cap Mondego Section 1. Its persistence into the supposedly non-marine Lusitanian might be a result of reworking but it could be suggested that the species has a high tolerance of salinity changes. No other calcareous nannofossils were found in the Lusitanian samples.

The assemblages extracted from the samples of the Cap Mondego Section 2 contained a good abundance of calcareous nannofossils which were generally well preserved (Text Fig. 17). Ellipsagelosphaera britannica, Ellipsagelosphaera keftalrempti and Watznaueria barnesae again dominate the assemblages. Stephanolithion speciosum and Stephanolithion speciosum var. octum are found throughout the section. Stephanolithion hexum is not found in the lowermost sample, 6021, but does occur in the remaining samples and has the same range in this section as Tetralithus gothicus.

Attempts to relate the calcareous nannofossil assemblages found here to established calcareous nannofossil zonal schemes and thereby clarify the stratigraphic position and extent of the section are unsatisfactory. This is because calcareous nannofossil biostratigraphy is not sufficiently refined for this particular period. It can only be said that the section lies within the Bathonian Stephanolithion speciosum Zone of AMEZIEUX (1972), MOSHKOVITZ and EHRLICH (1976) and THIERSTEIN (1976).



Text Fig. 17 Stratigraphic Distribution of Calcareous Nannofossils in the Cap Mondego Section 2.

3.3.4. The Alcanede-Carvalhos Road Section

This section is found on the road between Alcanede and Carvalhos, to the north of the junction with the road leading to Alcobertas.

Alcanede and Carvalhos lie north of Torres Vedras and east of the Peniche Peninsula. The section is located in Text Fig. 18.

The section has not been described specifically by any worker, although the general geological setting of the region has been considered by many.

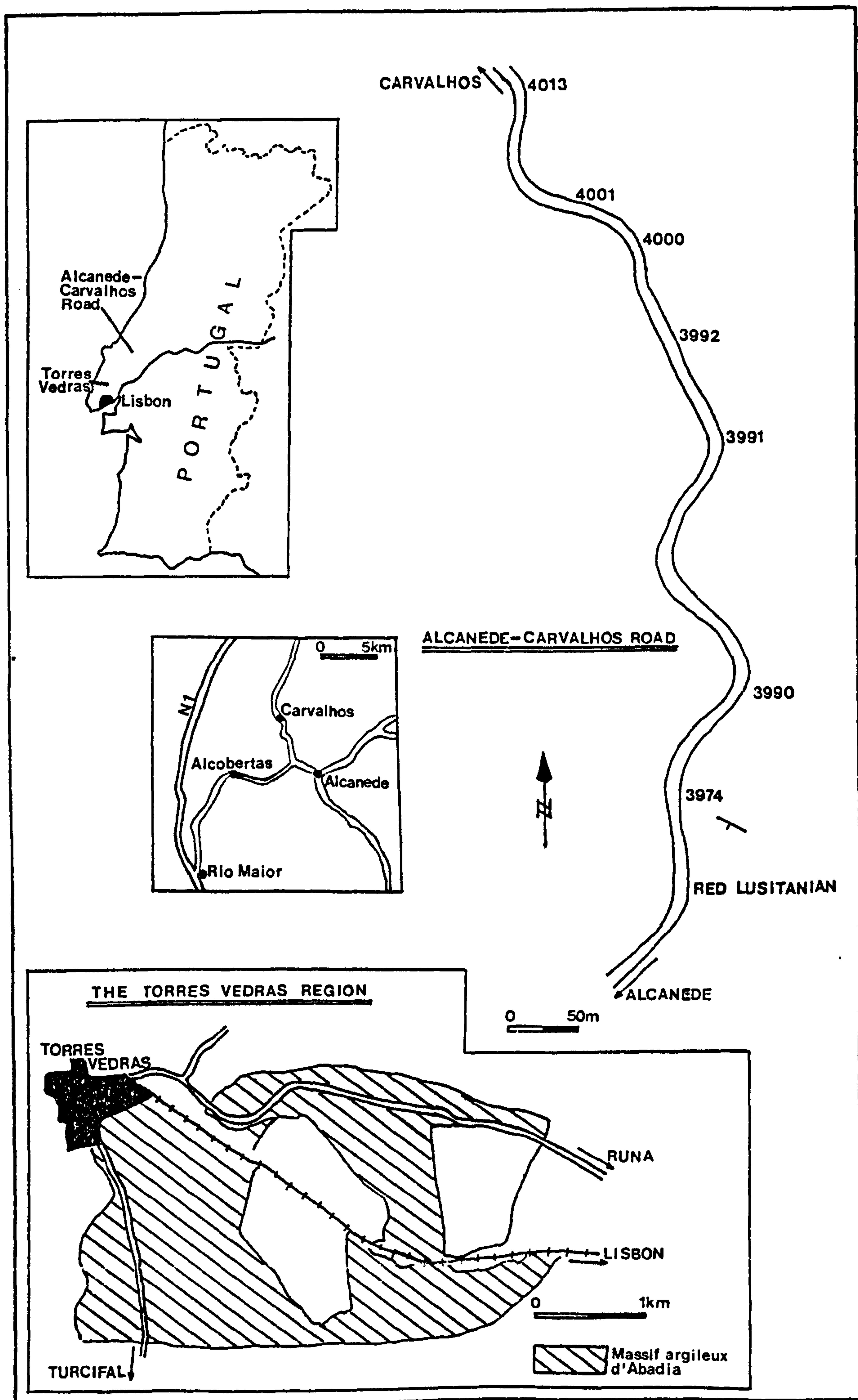
The samples were collected in a reverse order, that is from younger to older sediment. The collecting was started just north of the red, non-marine Lusitanian beds. Approximately 110 metres of section were sampled at various intervals depending on the lithology and the condition of the sediment. (Text Fig. 19).

The precise age of the section was not given in the field notebook; the sampled interval was recorded only as being in Lusitanian deposits. However, it is possible to make some inferences about the age of the section by considering the following:-

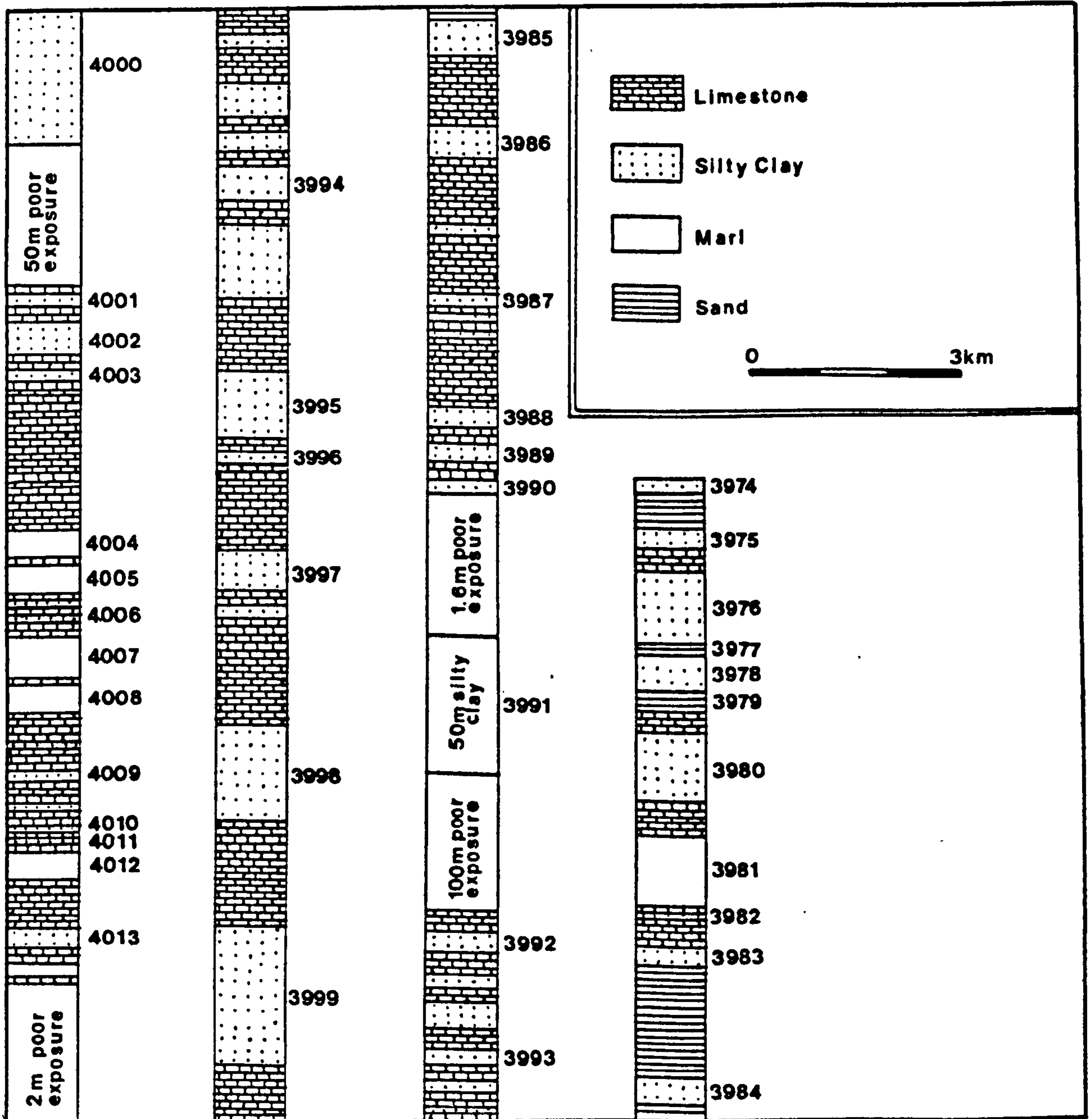
1. The calcareous nannofossil assemblages.
2. The geographical position of the section and its relationship to the marine regression which affected the sedimentary basin to the north of the River Tagus during the Callovian and Oxfordian stages.

1. The calcareous nannofossils

The assemblages contain a very poor abundance of specimens (see Text Fig. 20). They cannot provide any detailed information regarding the age of the section since they do not contain any biostratigraphically useful species. They can only indicate a Middle or Upper Jurassic age for the section. The assemblages are dominated by Tetralithus gothicus



Text Fig.18 The Portuguese Upper Jurassic Sections: Location.



Text Fig. 19 The Alcanede - Carvalhos Road Section: Lithology and Sample Distribution.

STAGE	CALCAREOUS NANNOFOSSIL ZONE	SAMPLE NUMBER	<i>W. barnesae</i>	<i>T. gothicus</i>	<i>S. punctulata</i>	<i>B. ellipticum</i>	<i>D. ignotus</i>	<i>E. keftalrempti</i>	<i>C. margerell</i>	<i>E. britannica</i>	<i>Z. noeli</i>	<i>S. quadriarculus</i>	<i>P. cylindricus</i>
LUSITANIAN	(Not determinable)	3974											
		3975											
		3976											
		3977											
		3978											
		3979											
		3980											
		3981											
		3982											
		3983											
		3984											
		3985											
		3986											
		3987											
		3988											
		3989											
		3990											
		3991											
		3992											
		3993											
		3994											
		3995											
		3996											
		3997											
		3998											
		3999											
		4000											
		4001											
		4002											
		4003											
		4004											
		4005											
		4006											
		4007											
		4008											
		4009											
		4010											
		4011											
		4012											
		4013											

 Very Common
 Common
 Rare
 Inferred

Text Fig. 20 Stratigraphic Distribution of Calcareous Nannofossils in the Alcanede-Carvalhos Road Section.

DEFLANDRE 1959, the species which was the sole representative in the non-marine Lusitanian deposits at Cap Mondego. The close proximity of the red, non-marine sediments to the sampled interval on the Alcanede-Carvalhos Road suggests that the section is unlikely to be in fully marine sediments. This might explain the low species diversity and poor abundance of calcareous nannofossils in the assemblages. The dominance of Tetralithus gothicus in these possibly marginal marine deposits again suggests that this species has a high tolerance of salinity changes.

2. The location of the section

The Alcanede-Carvalhos Road Section lies in the southern part of the sedimentary basin which was affected by the Callovian/Oxfordian regression. The section also lies just north of the Torres Vedras region, which is also in the northern sedimentary basin. However, the marine regression, which is thought to have started during the Middle Callovian in the north of the basin, was not so pronounced in the southern part of the basin near to Torres Vedras. In this area marine deposition was more consistent during the Lusitanian period.

The presence of non-marine deposits in the Alcanede-Carvalhos Road area confirms that the regression did reach as far south as this area but probably not until a later stage in the Lusitanian. From this it is tentatively suggested that the sampled section is of Lower to Middle Lusitanian age.

3.3.5. The Torres Vedras Section

The choice of the area round Torres Vedras (Text Fig. 7, 18) as the type area of CHOFFAT's Lusitanian stage is justified because in this region the deposits are in marine facies. Further to the north

in the sedimentary basin the Lusitanian is found in fresh or brackish water deposits. Since the pioneering work of CHOFFAT (1893) the area has been studied by many workers (FRANCA et al 1964; MOUTERDE et al 1971; RAMALHO 1971; RAMALHO and REY 1975; RUGET-PERROT 1961) because of the great interest that surrounds the Lusitanian stage and its correlation with other stratigraphic schemes.

RUGET-PERROT (1961) described the best exposure of Lusitanian in the area as lying between the road from Torres Vedras to Runa and the road from Torres Vedras to Lisbon via Turcifal. (See Text Fig. 18.) The precise location of the section which was sampled for this study was not given in the field notebook. However, it is known that the section was taken in a newly excavated area for housing estate foundations on the road from Torres Vedras to Turcifal.

From the map in Text Fig. 18 it can be deduced that the section was in the "Massif argileux d'Abadia". In his description of the Lusitanian stage, CHOFFAT (1893) defined the "Couches d'Abadia" as being at the top of the stage, as is shown in Text Fig. 6. RUGET-PERROT (1961) showed that the "Couches d'Abadia" contain a typically Lower Kimmeridgian ammonite fauna and so, suggested that the Lusitanian/Kimmeridgian boundary be lowered as is also shown in Text Fig. 6. If the "Massif argileux d'Abadia" is the same as the "Couches d'Abadia" then it can be tentatively suggested that the sampled section is in sediments of Lower Kimmeridgian age. However, the author regards this as most unsatisfactory since it has not been possible to establish whether or not the two terms refer to the same deposits.

The calcareous nannofossil assemblages suggest that the sediments are not entirely of Lower Kimmeridgian age. The range chart in Text Fig. 21 shows that there are three notable biohorizons within the sampled interval.

STAGE	CALCAREOUS NANNOFOSSIL ZONE	SAMPLE NUMBER	<i>S. punctulata</i>	<i>E. britannica</i>	<i>B. ellipticum</i>	<i>E. keftalremptii</i>	<i>W. barnesae</i>	<i>T. gothicus</i>	<i>D. ignotus</i>	<i>Z. noeli</i>	<i>C. margerelli</i>	<i>Z. erectus</i>	<i>P. cylindricus</i>	<i>S. asymmetricus</i>	<i>D. patulus</i>	<i>S. quadriculatus</i>	<i>S. bigoti</i>	<i>E. gallicus</i>	<i>P. madingleyensis</i>	<i>A. geometricus</i>	<i>T. patulus</i>	<i>W. biporta</i>	<i>H. cuvillieri</i>	<i>Z. elegans</i>	<i>R. schizobrachiata</i>		
KIMMERIDGIAN	<i>P. madingleyensis</i> Zone	3970																									
		3969																									
		3968																									
OXFORDIAN		3967																									
		3966																									
		3965																									
		3964																									
		3963																									
		3962																									
		3961																									
		3960																									
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		3948																									
		3947																									
		3946																									
		3945																									
		3944																									
		3943																									
CALLOVIAN	<i>S. bigoti</i> Zone	3942																									
		3941																									
		3940																									
		3939																									
		3938																									
		3937																									
		3936																									
		? BATHONIAN?	?	3935																							
				3934																							
				3933																							
3932																											
3931																											
3930																											
3929																											
3928																											
3927																											
3926																											

Common

Rare

Inferred

Common

Rare

Inferred

Text Fig. 21 Stratigraphic Distribution of Calcareous Nannofossils in the Torres Vedras Section.

1. The base of Stephanolithion bigoti DEFLANDRE 1939.

This biohorizon is thought to indicate a basal Callovian age (AMEZIEUX 1972; BARNARD and HAY 1974; MOSHKOVITZ and EHRLICH 1976; STRADNER 1963; THIERSTEIN 1976) although the horizon marker species was not recorded at this level in the Cap Mondego area.

2. The base of Polypodorhabdus madingleyensis BLACK 1968.

This biohorizon has been recorded as being of Middle Callovian age (BARNARD and HAY 1974) and Lower Oxfordian age (THIERSTEIN 1976). In this work the marker species is recorded in Upper Callovian deposits on the Isle of Skye.

3. The top of Stephanolithion bigoti.

This biohorizon has been cited as defining the top of the Oxfordian (STRADNER 1963; THIERSTEIN 1976) although AMEZIEUX (1972) did find the marker species in Lower Kimmeridgian deposits.

The calcareous nannofossils therefore indicate a Callovian to Lower Kimmeridgian age for the section. However, the absence of typically Bathonian species (Stephanolithion speciosum DEFLANDRE 1954 and Stephanolithion speciosum var. octum ROOD & BARNARD 1972) in the lower part of the section, which is supposedly Middle Jurassic in age, suggests that this evidence should be regarded with caution. It might be, for example, that the ranges of the selected biohorizon marker species are not fully represented in the section because of poor preservation of the fossil assemblages. Also, MOUTERDE et al (1971) considered that the Upper Jurassic marine transgression which followed the Callovian/Oxfordian regression did not begin in this part of Portugal until the Middle Oxfordian. Thus, while it can be suggested from the calcareous nannofossils that the section is probably not

restricted to the Lower Kimmeridgian, the assignment of an age to this section is confused and very tentative.

4. THE ISLE OF SKYE

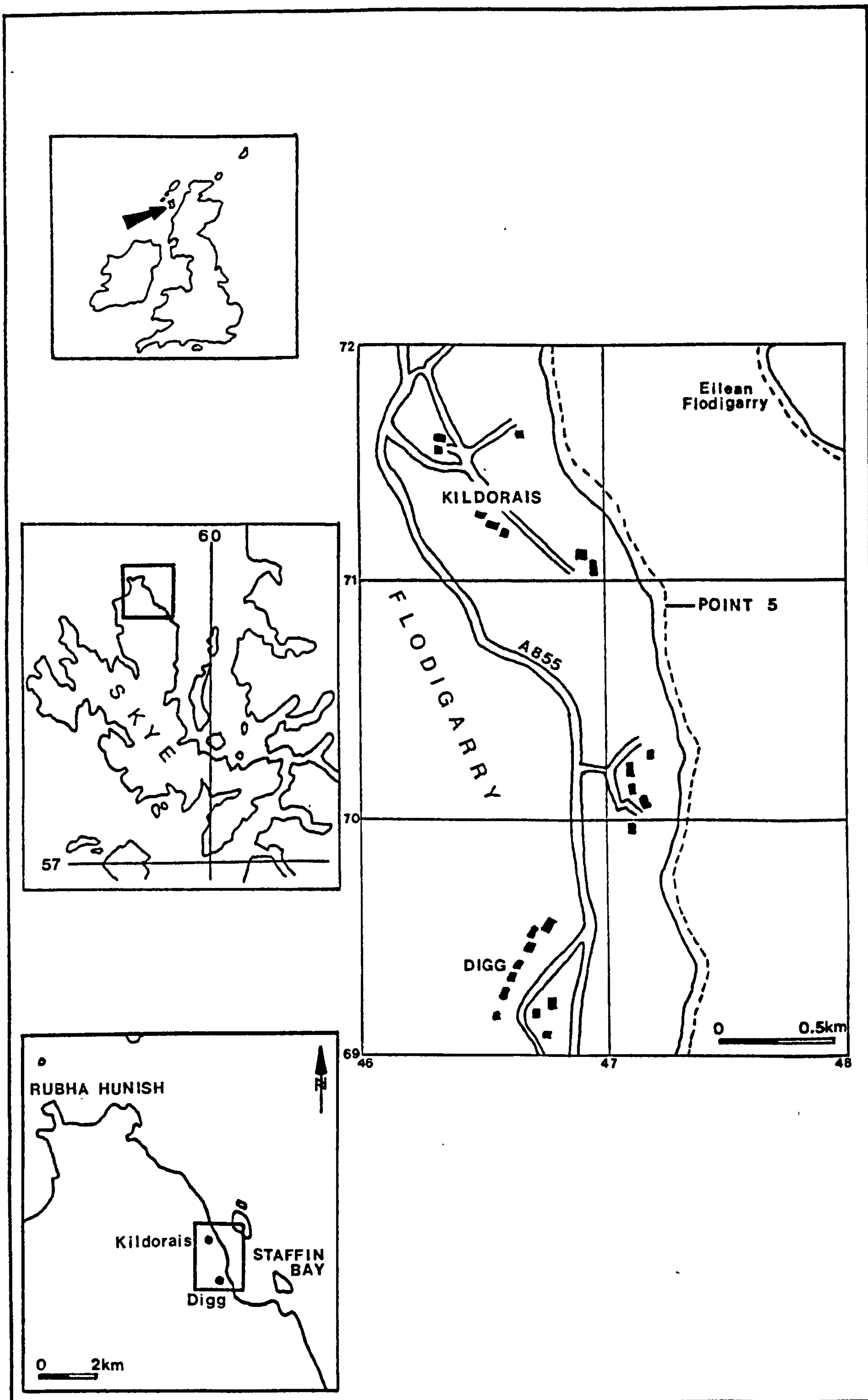
4.1. Introduction and review of previous work

Fifteen samples from part of the Upper Jurassic of Great Britain were made available to the author for analysis during this study. The examination of Upper Jurassic material from Britain provides a valuable opportunity for comparison of the Portuguese Lusitanian assemblages with those in material from coeval deposits in other areas. It was hoped that this work, and further comparison with Upper Jurassic sediment from the western North Atlantic (discussed elsewhere) might lead to a greater understanding of the Lusitanian stage in Portugal. The work has been published by the author during her period of study for this degree (HAMILTON 1978) and appears at the back of this volume.

The samples came from a section of Middle Callovian to Lower Oxfordian age in the Staffin Shale Formation from the Isle of Skye. The location of the section is given in Text Fig. 22.

The name Staffin Shale Formation (TURNER 1966, emended SYKES 1975) was proposed for the dark grey shales of Middle Callovian to Lower Kimmeridgian age which occur between Kildorais and Digg, in North Skye. They have been examined by many workers since MACCULLOCH (1819) gave the first account of the geology of Skye. Much of the early work was concerned with lithological description and most of it considered the sediments at Staffin in the wider context of the Mesozoic rocks of Scotland (BRYCE 1873; FORBES 1851; JUDD 1878; LEE and PRINGLE 1931; MURCHISON 1827). MACGREGOR (1934) reviewed past work and gave an account of the rocks with detailed descriptions of some sections.

The sections at Staffin are of particular interest because they provide one of the most complete records of rocks of Middle Callovian



Text Fig.22 The Staffin Bay Section: Location.

to Lower Kimmeridgian age in Britain and are entirely argillaceous, in contrast to their equivalents in England, the Oxford Clay, Corallian Beds and the lower part of the Kimmeridge Clay (ANDERSON and DUNHAM 1966). TURNER (1966, 1970) showed that all the standard ammonite zones from the Middle Callovian (jason Zone) to the Middle Oxfordian (plicatilis Zone) can be recognised and that the sections are probably complete into the Lower Kimmeridgian. WRIGHT (1973) added further details though his study does not cover that part of the section examined here. SYKES (1975) divided the formation into five members and suggested that it represents an offshore, possibly outershelf sequence.

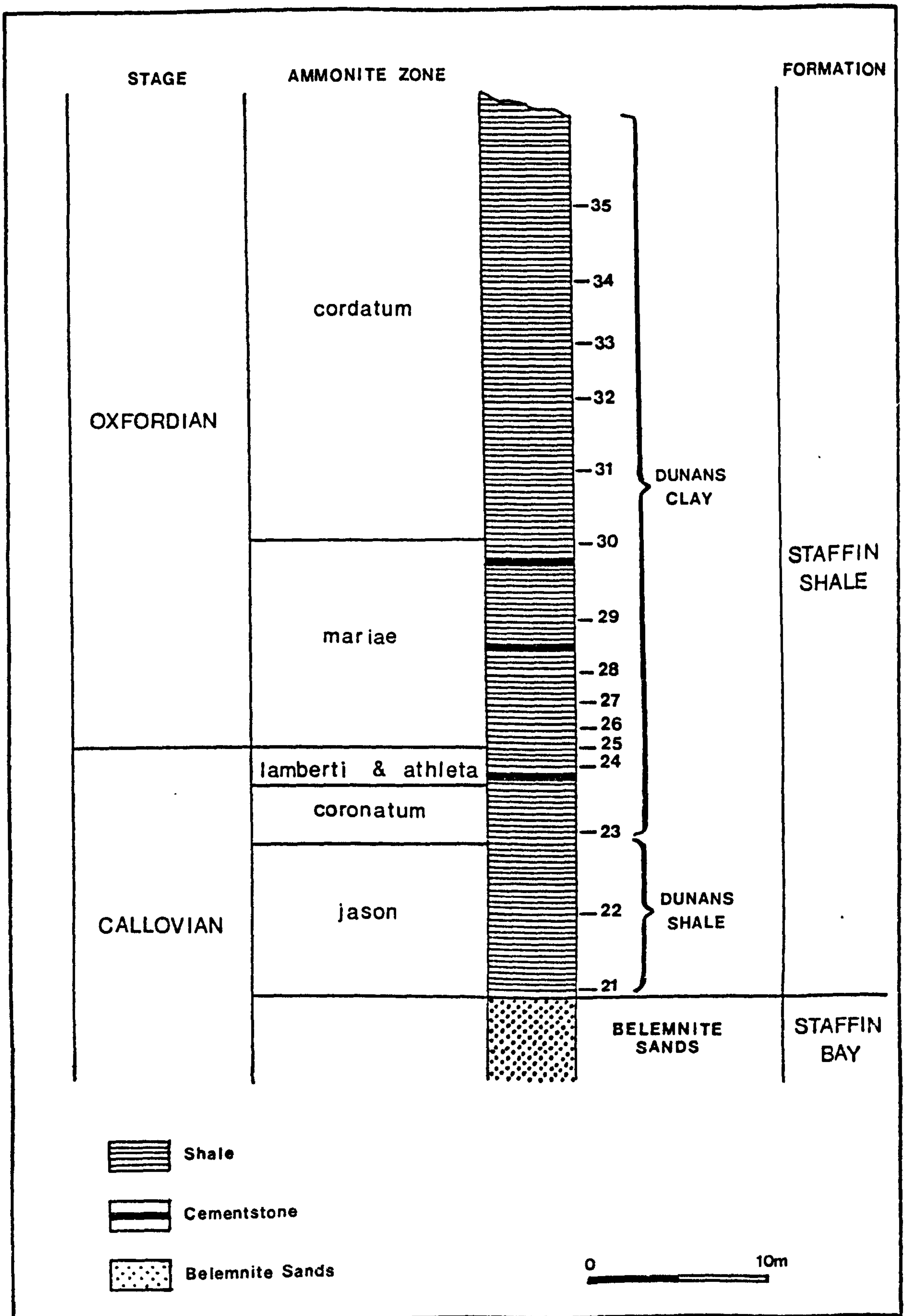
The identification of almost all the Callovian and Oxfordian ammonite zones at Staffin has provided a framework upon which investigations into the distribution of calcareous microfossils may be made. CORDEY (1962) recorded 46 species of foraminifera from a section which covers the lamberti, mariae and cordatum Zones. The lower part of his section, which he supposed to be of jason, coronatum and athleta Zone age, contained no foraminifera. He listed separately ten species which were considered to have restricted ranges, though only four are known in other areas. Citharina flabelloides (TERQUEM) is recorded from the Middle and Upper Jurassic of North-west Germany and Nodosaria minuta WISNIEWSKI and Fronicularia moelleri UHLIG are Upper Jurassic species. Citharinella exarata LOEBLICH & TAPPAN has a more restricted range being characteristic of the Oxfordian in Britain. The ostracods show a similar distribution to the foraminifera, in that sediments of the lamberti, mariae and cordatum Zones yield ostracods but the lower part of the section is barren (WHATLEY 1970). Of the 23 species recorded, Lophocythere cruciata oxfordiana LUTZE, Lophocythere cruciata intermedia LUTZE, Lophocythere scabra bucki

LUTZE and Furbergiella horrida horrida BRAND & MALZ, whose ranges are known in Great Britain, France, North-west and southern Germany, collectively indicate sediments of Callovian/Oxfordian boundary age.

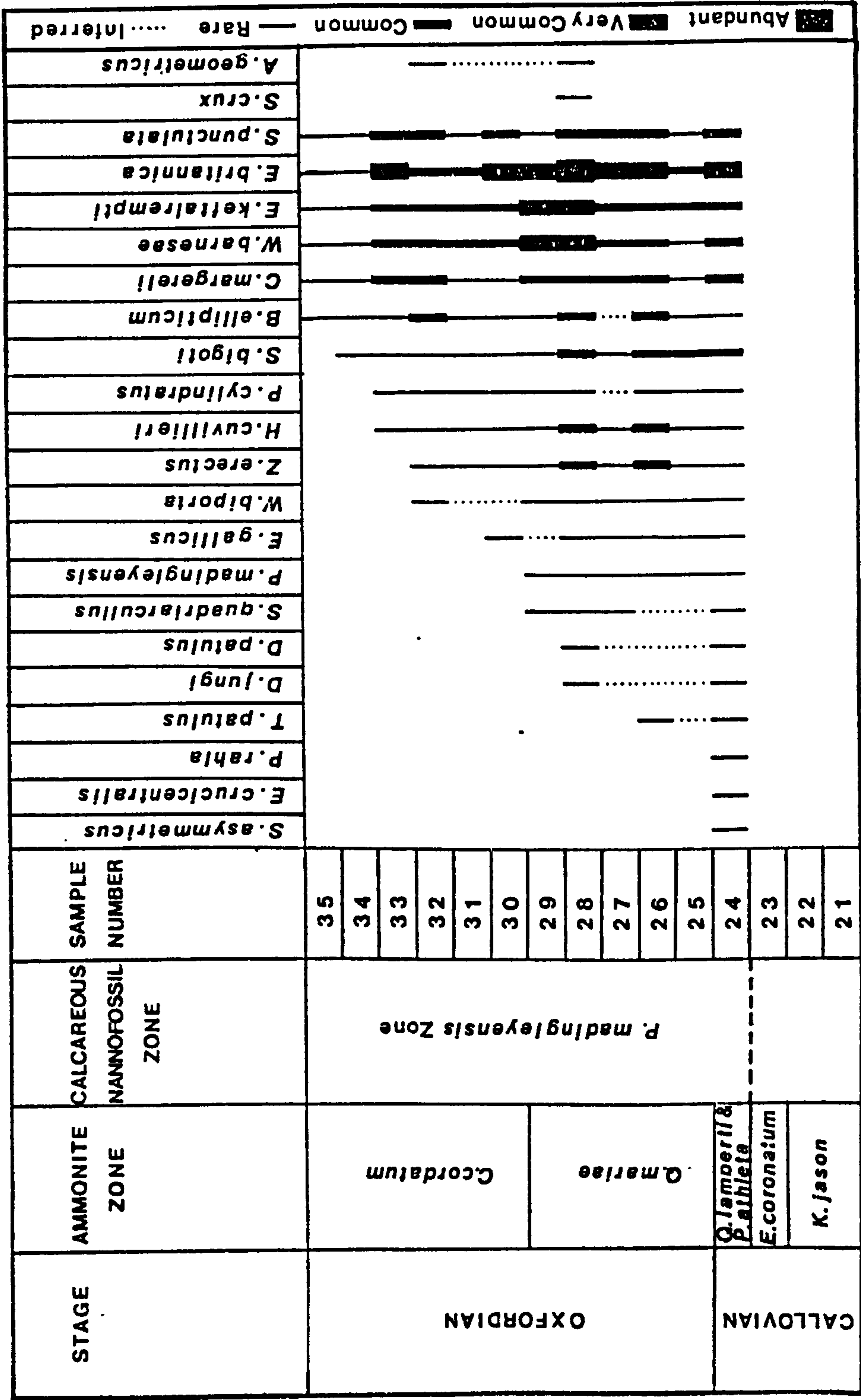
4.2. The Staffin Bay Section

The fifteen samples examined in this study came from a section at Point 5, Staffin Bay (NG 472708), described by ANDERSON and DUNHAM (1966, Figs. 10, 12), and illustrated here in Text Fig. 23. The range chart in Text Fig. 24 clearly shows that the uppermost samples (34 and 35) contained a poor assemblage of calcareous nannofossils and that the lowest three (21 - 23) were barren. The latter were from the jason and coronatum Zones where foraminifera and ostracods are also absent (CORDEY 1962 and WHATLEY 1970).

Clearly, the calcareous nannofossil assemblages are dominated by Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968. Of the other species that are found in all the samples Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 and Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 are common, while Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975 and Cyclagelosphaera margereli NOEL 1965 are more rare. These together with Podorhabdus cylindratus NOEL 1965, Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938, Staurorhabdus quadriarculus (NOEL 1965) NOEL 1973, Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 and Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971 are long ranging species, some of which are known throughout the Jurassic and even into the Cretaceous. The remaining species, especially Actinozygus geometricus (GORKA 1957) ROOD, HAY & BARNARD 1971, Polypodorhabdus madingleyensis BLACK 1968 and Stephanolithion bigoti DEFLANDRE 1939, have more restricted ranges. The absence of these species in the upper part of this section is likely to be a preservation



Text Fig. 23 The Staffin Bay Section : Lithology and Sample Distribution.



Text Fig. 24 Stratigraphic Distribution of Calcareous Nannofossils in the Staffin Bay Section.

phenomenon rather than a feature of biostratigraphic importance.

The total assemblage indicates a Callovian/Oxfordian age for the section.

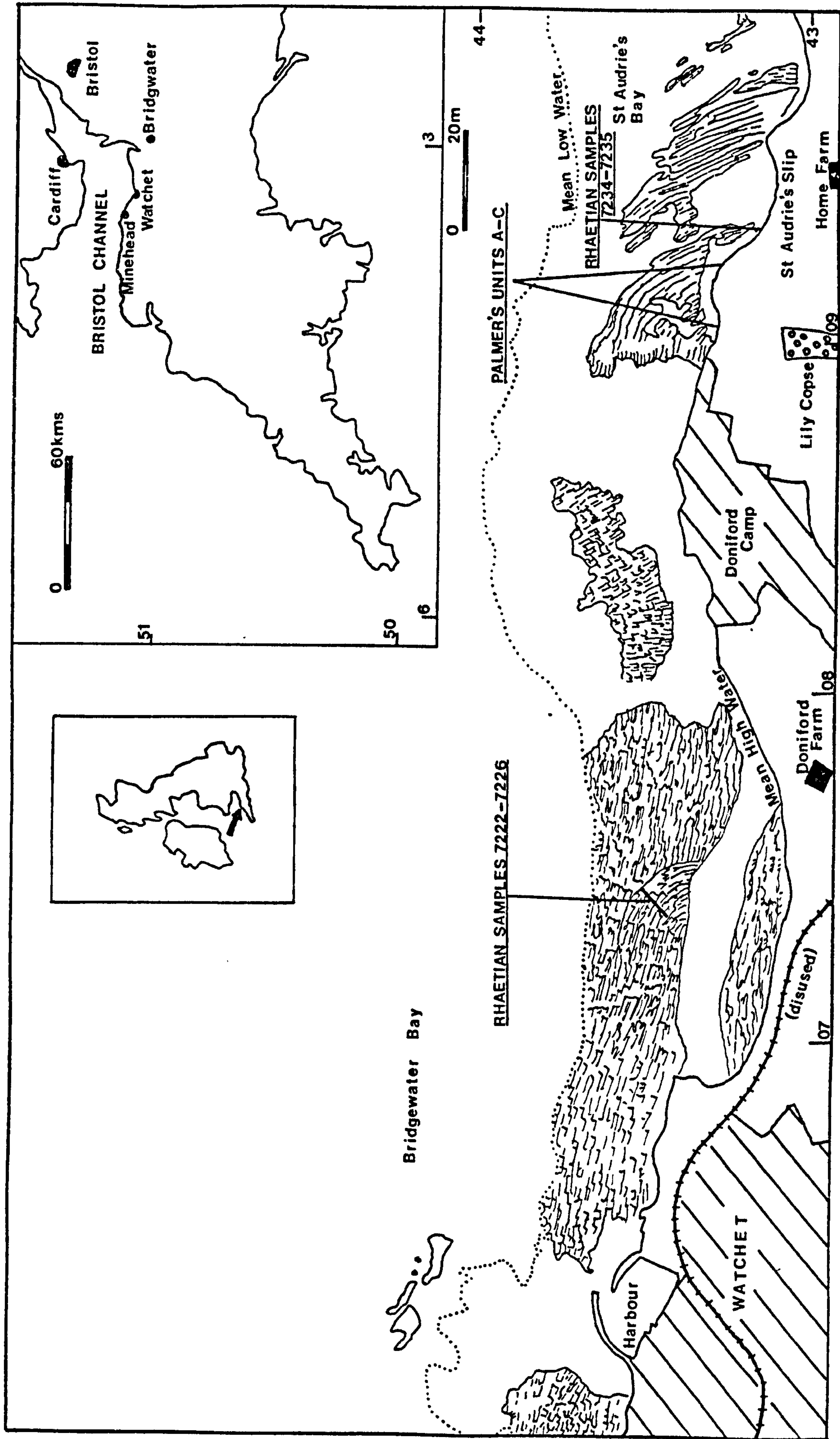
5. WATCHET, NORTH SOMERSET

5.1. Introduction and review of previous work

Sediments of Triassic and Lower Jurassic age are exposed in a coastal section near Watchet in North Somerset in a series of faulted blocks. Some Rhaetian and Hettangian samples from this area were made available to the author by Dr. A.R. Lord and this provided a valuable opportunity for the author to investigate the early and pre-Jurassic development of calcareous nannofossils. Very little is known about this aspect of the group partly, perhaps, as a result of the lack of suitable sediment of pre-Jurassic age. BARNARD and HAY (1974) studied the lowermost Jurassic period and PRINS (1969) briefly examined the Rhaetian stage.. Also AMEZIEUX (1972) and THIERSTEIN (1976) referred to PRINS' pre-Jurassic record and finally, PIRINI RADRIZZANI (1971) described possible calcareous nannofossils from the Permian of Turkey.

Early work on the Triassic and Lower Jurassic in South-west England (BRISTOW and ETHERIDGE 1873; DAWKINS 1864; ETHERIDGE 1872; HORNER 1816; WOODWARD 1893) mainly considered the geology of North Somerset within the general context of the Lower Jurassic of Great Britain and did not involve detailed bed by bed studies of the succession. HORNER (1816), for example, recognised the red Triassic marl and the blue grey "lyas" but did not attempt to work out a continuous section because of the numerous faults which affect the area.

RICHARDSON (1911) made a detailed study of the Rhaetian Series which lies between the Keuper or Upper Triassic and Lower Jurassic. He described a measured section at St. Audries Slip (see Text Fig. 25 for location). Following RICHARDSON, two important studies (LANG 1924, TRUEMAN 1920) described the Lias of the Devon and Dorset area and the



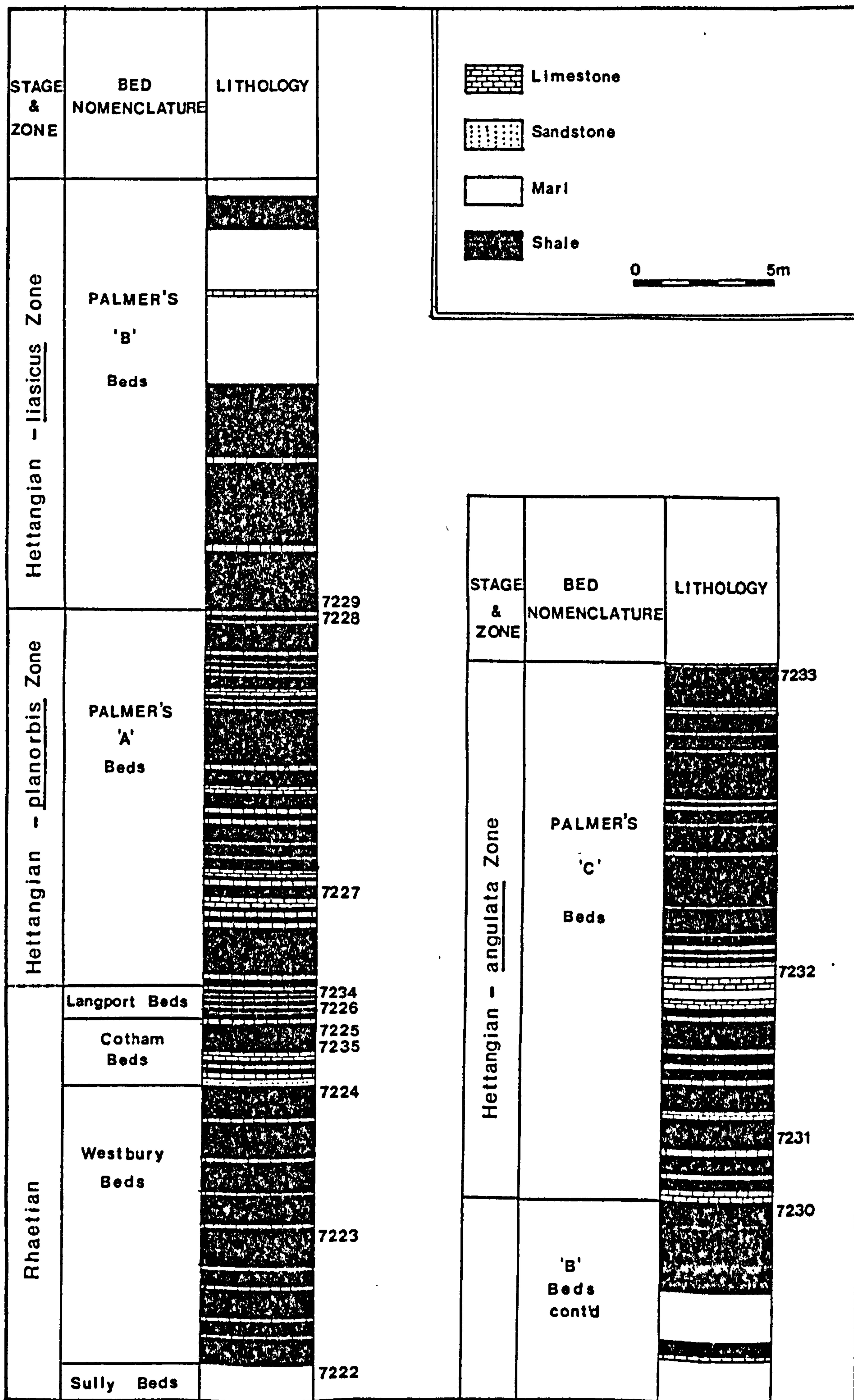
Text Fig. 25 The Watchet Section: Location and Sample Distribution.

Lias of the Cardiff district respectively. The Lower Jurassic of North Somerset was neglected, being only briefly mentioned by ARKELL (1933), until the recent publication of PALMER (1972) which gives a detailed description of the Lias succession at Watchet. PALMER noted that "while North Somerset coastal Lias is composed of the usual alternations of blue grey limestones and black shales or marls" resembling the Blue Lias of the Dorset-Devon coast, it differs in that "the succession is not a uniform series of limestone-shale alternations but is interrupted by thick developments of shale and paper shale". He subdivided the Lower Lias into seven divisions, labelled A-G, which roughly cover the interval from the planorbis to semicostatum Zones.

5.2. The Watchet Section

The sample collection for the Rhaetian part of this study followed RICHARDSON's (1911) section while the Hettangian samples were collected with reference to PALMER's (1972) section covering Units A-C (planorbis to angulata Zones). The lithology and the sample distribution of the Watchet section are illustrated in Text Fig. 26.

The succession starts with the Lower Rhaetian, marly, Sully Beds from which one sample was taken. Overlying these RICHARDSON recorded the Westbury Beds, which are black shales of Lower Rhaetian age. The Upper Rhaetian was subdivided by RICHARDSON into the Cotham Beds, Langport Beds and Watchet Beds. The Cotham Beds are largely composed of interbedded sandstones, shales and limestones. The passage from the Cotham Beds to the Langport Beds is not lithologically distinct but RICHARDSON noted a marked palaeontological change at the boundary which led him to suggest a pause in the normal sequence of deposition. The Sun Bed, which is a ripple marked silty limestone, is found at the



Text Fig. 26 The Watchet Section: Lithology and Sample Distribution.

top of the Langport Beds. RICHARDSON's Watchet Beds differ noticeably in their lithology from the preceeding beds being fine grained greyish argillaceous deposits. PALMER (1972) suggested that the Watchet Beds should be included in the Lias rather than in the Rhaetic since they are lithologically similar to Lias deposits and since they show no evidence of deposition in the shallow water conditions which prevailed during the Rhaetian stage. It seems likely that the Watchet Beds were deposited during the deepening of the seas associated with the transgressive phase that followed the Rhaetian stage. Following this scheme the Sun Bed would therefore mark the top of the Rhaetian stage. The author adopts PALMER's proposal but notes that his is a lithostratigraphic scheme which does not coincide with the chronostratigraphic definition of the Rhaetian-Hettangian boundary based on the presence of the zonal ammonite Psiloceras planorbis. This anomaly is demonstrated in Text Fig. 27. The absence of ammonites in the beds which are in lithological continuity with the younger, ammonite bearing deposits is normally covered by applying the term "pre-planorbis" to these beds. This hiatus may also be covered by using the lamellibranch, Ostrea liassica, as a zonal marker. This scheme allows the base of the Lower Jurassic (chronostratigraphic system) to be equivalent to the base of the Lias (lithostratigraphic system).

The fourteen samples which were examined from the Watchet Section yielded very restricted calcareous nannofossil assemblages. The stratigraphic distribution of the species is illustrated in Text Fig. 27. The lowermost sample, 7222, was barren. Samples 7223 and 7224 contained a few specimens which were similar to Annulithus arkelli ROOD, HAY & BARNARD 1974 but whose identification is tentative. The remaining samples, which are of Upper Rhaetian and Hettangian age, yielded

CHRONOSTRATIGRAPHIC SUBDIVISION	AMMONITE ZONE	LITHOSTRATIGRAPHIC SUBDIVISION	BED NOMENCLATURE After PALMER (1972) - LIAS RICHARDSON (1911) - RHAETIC	CALCAREOUS NANNOFOSSIL ZONE	SAMPLE NUMBER	A. arkelli	S. punctulata	
HETTANGIAN	angulata	LIAS	PALMER'S 'C' BEDS	A arkelli Zone	7233	
	liasicus				C48			7232
					C20			7231
	planorbis				C6			7230
					B15			7229
			B1		7228			
RHAETIAN	-----	RHAETIC	'A' BEDS		A31			7227
					A9			7234
			LANGPORT BEDS					7226
			COTHAM BEDS					7225
			WESTBURY BEDS					7235
					7224			
					7223			
			SULLY BEDS		7222			

Abundant Very Common Common Rare

.....

 Inferred

Text Fig. 27 Stratigraphic Distribution of Calcareous Nannofossils in the Watchet Section.

specimens of Annulithus arkelli and Schizosphaerella punctulata

DEFLANDRE & DANGEARD 1938, the latter becoming common at the top of the section. No other calcareous nannofossils were recorded.

6. THE WESTERN NORTH ATLANTIC

6.1. Introduction

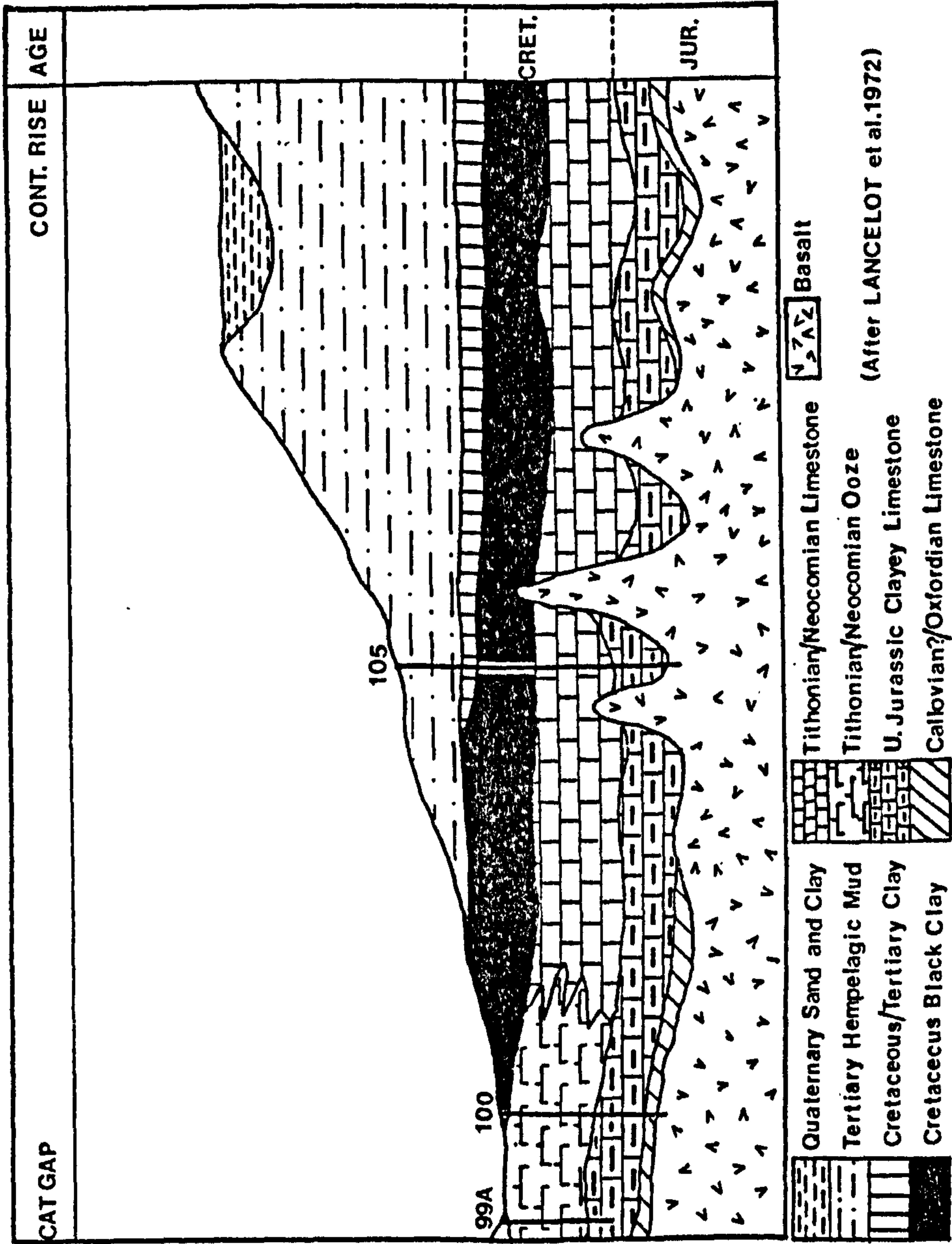
76 samples of approximately 1 cc in size were obtained from the Curator of the Deep Sea Drilling Project in May 1976. The material came from Leg 11 of the Deep Sea Drilling Project in which the Glomar Challenger drilled 11 holes (Sites 98 - 108) in the western North Atlantic during 1970. (Text Fig. 28.) The principal objective of this part of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) programme was to recover the oldest in-place material from the top of the ocean crust as near as possible to the continental margin in an attempt to date the age of the western Atlantic and, following modern concepts of sea floor evolution, infer the age of the break up of North America and Africa.

During the drilling sediment of Jurassic age suitable for the study of calcareous nannofossils was recovered at sites 99A, 100 and 105.

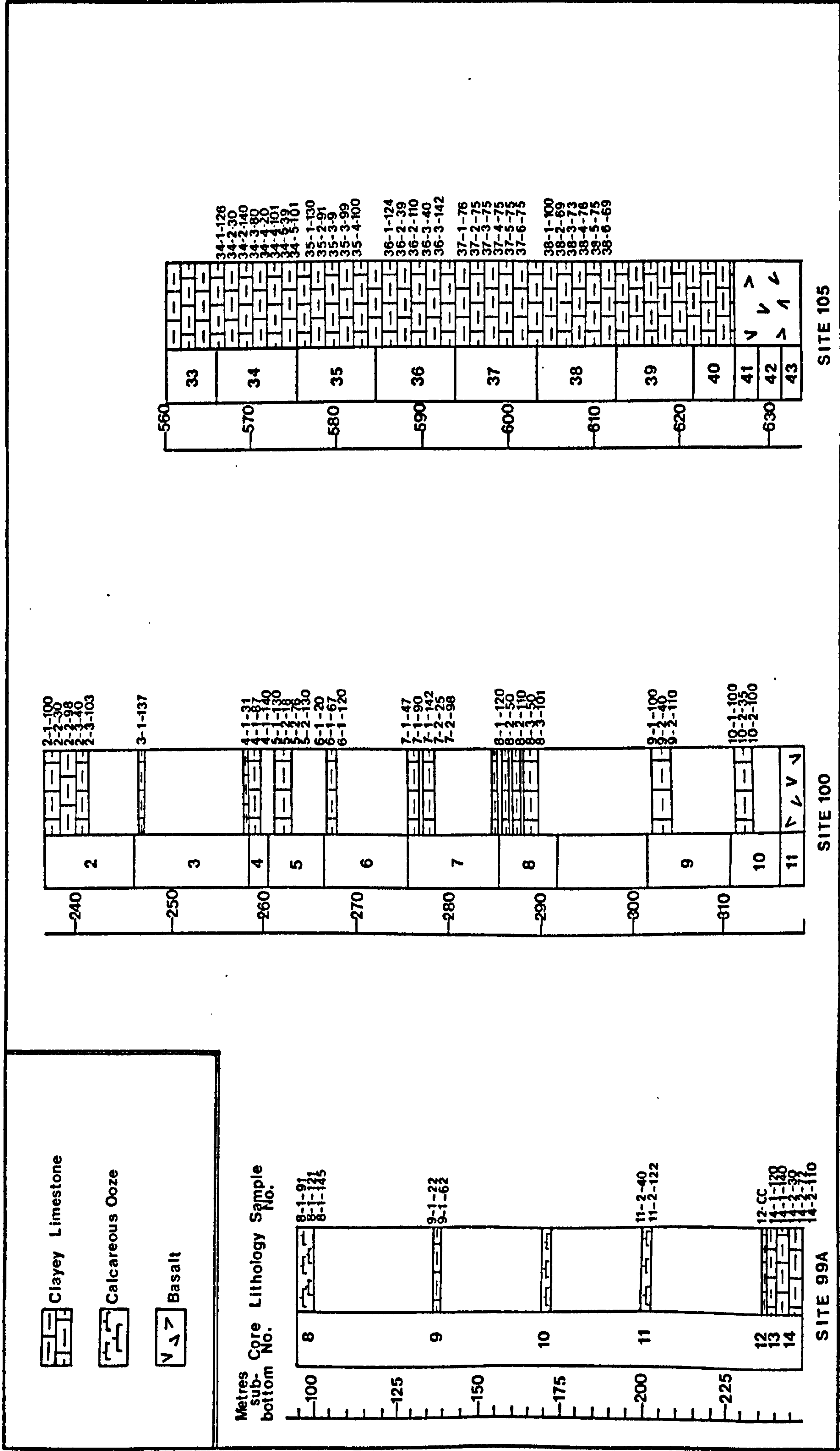
The organisational structure of the Deep Sea Drilling Project dictates that shipboard scientists produce an initial report of the preliminary results concerning drilling progress, lithology and stratigraphy for each site. Commonly, subsequent shore based studies are made. In this case the great interest which surrounded Leg 11, because of the nature of its objectives, resulted in a considerable amount of land based work being done on the material. (AKERS 1972; BERNOULLI 1972; BUKRY 1972; CARON 1972; EWING and HOLLISTER 1972; HABIB 1972; HESS 1972; HOTTINGER 1972; LANCELOT, HATHAWAY and HOLLISTER 1972; LEHMANN 1972; LUTERBACHER 1972; OERTLI 1972; RENZ 1972; WILCOXON 1972a, 1972b; WYLIE POAG 1972, for example). The final volume of information concerning the Deep Sea Drilling Project gives a very detailed and



Text Fig. 28 Geographic Distribution of Deep Sea Drilling Project Sites 98-108.



Text Fig. 29 Facies Distribution in the Western North Atlantic.



thorough account of the results.

With this in mind, no analysis of Deep Sea Drilling Project cores which were drilled several years ago is likely to be original work. The samples were obtained for this study because their almost continuous coverage of the Upper Jurassic provided a valuable opportunity for the author to further investigate the stratigraphic position of the Upper Jurassic Portuguese sections by actual comparison of the calcareous nannofossil assemblages rather than by a literature comparison.

6.2. Deep Sea Drilling Project Sites 99A, 100 and 105

The location map (Text Fig. 28) shows that the sampled sites (99A, 100 and 105) can be separated into two distinct geographic areas. Sites 99A and 100 are in the Cat Gap area, to the east of Miami and north of Cuba while Site 105 is located approximately 400 miles to the north, off Cap Hatteras and between New York and Bermuda.

6.2.1. Facies distribution

The sketch diagram of the distribution of different facies in Text Fig. 29 shows that a wide range of sediments was found in the cores. At Site 99A recovery was very poor, as is shown in the core summary in Text Fig. 30. Also, some contamination by down-hole caving originating from the detrital layer which contains a Paleocene-Early Miocene fauna was recorded. Most of the sediment recovered at this site was calcareous nannoplankton oozes and chalks interbedded with hard chert layers. The oldest sediments were Oxfordian or Kimmeridgian white, pale red and greenish grey indurated limestone and red clayey oozes. Overlying these were light grey chalks, nannoplankton oozes and cherts of Tithonian age.

At Site 100 greenish grey homogeneous limestones were found above the basaltic basement. Dark grey specks and streaks which seem to have had an organic origin were found. Burrowing was common in this layer which suggests a well oxygenated environment of deposition. This limestone contained floral assemblages indicative of an Oxfordian or possibly Callovian age and therefore was thought to represent the oldest sediment hitherto recovered from the ocean floor. Overlying the limestone there were red clayey limestones of Oxfordian to Kimmeridgian age. These contained green coloured bands or patches which were not necessarily confined to bedding planes and may have resulted from organic material present in some layers or zones causing reduction, removal of iron oxide and a change in colour from red to green. The upper part of this unit showed flow structures, current bedding and slump structures indicating deposition in an active environment.

The core summary chart for Site 105 shows a much more continuous recovery at this site. Here, the red and green clayey, Oxfordian to Kimmeridgian limestone was found above the basaltic basement. The abundance and variety of fossils in these beds suggested deposition in a bathyal environment shallower than the present depth at this site.

The diagram showing the distribution of different facies illustrates that most of the lithological facies have a basin wide extension. LANCELOT, HATHAWAY and HOLLISTER (1972) summarised the evolution of the North Atlantic basin in their "cruise synthesis".

6.2.2. Sampling

In Text Fig. 30 the distribution of the samples in the three selected cores is illustrated. The sample numbering system is that used by the Deep Sea Drilling Project. On the Glomar Challenger the

core barrels are 9.1 metres long and are equipped with a detachable retaining device, the core catcher. Samples from this portion are labelled "cc". Following a core run, the approximately 9 metres of core are cut into six, 1.5 metre sections which are numbered from the top of the core. Material sampled within one of these sections is measured in centimetres from the top of the section. Thus, the sample designation is given in the following order:

1. Cruise Leg Number (omitted in this study)
2. Drill Hole Designation - including a suffix e.g. A if more than one hole is drilled at the site.
3. Core Number
4. Core Section
5. Sample Interval below the top of the Core Section.

For example 11/105/34/1/126-127

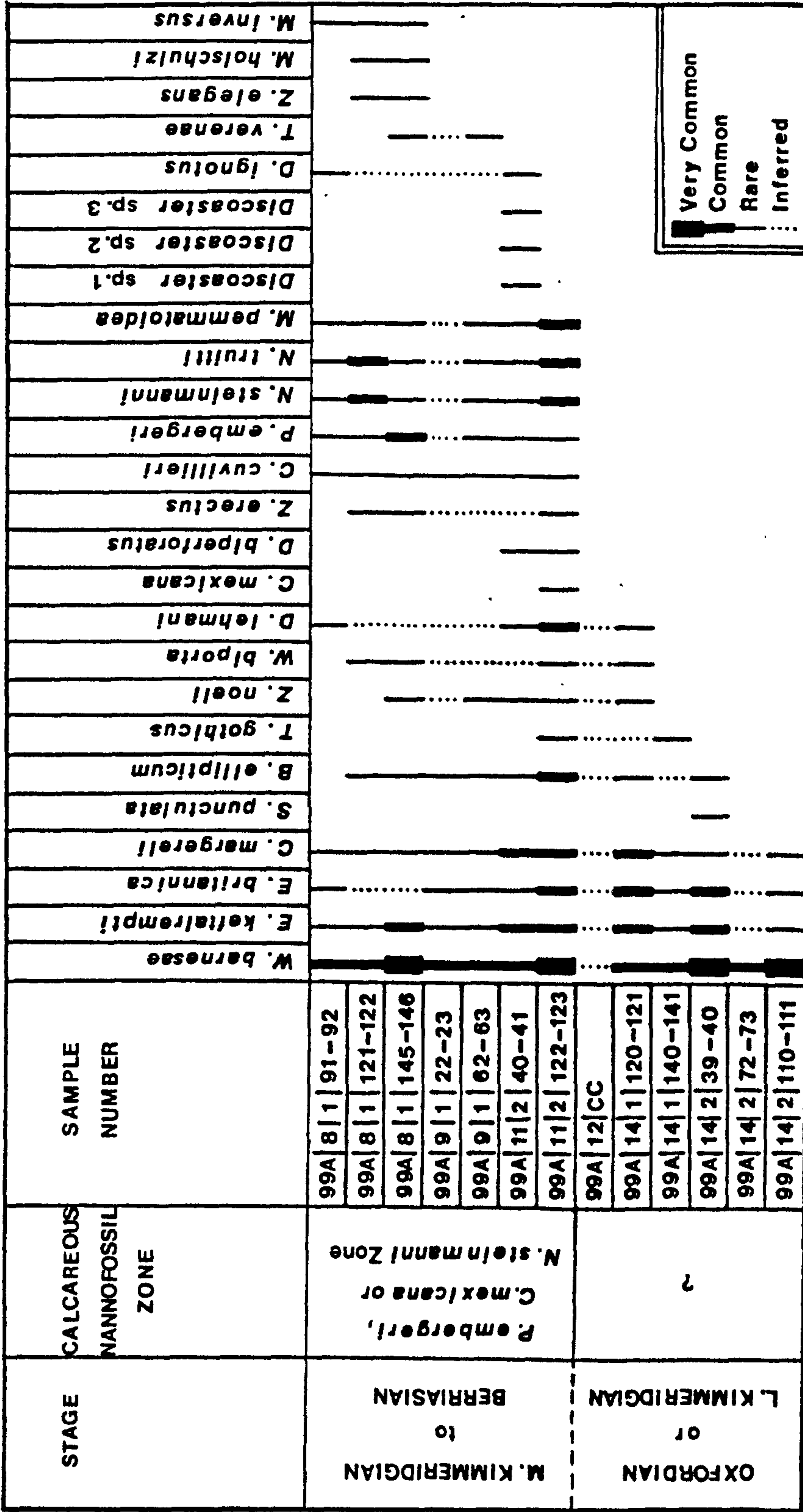
11/99A/8/1/91-92

6.3. The calcareous nannofossils

6.3.1. Deep Sea Drilling Project Site 99A

Thirteen samples from Hole 99A were examined. The calcareous nannofossil assemblages were very well preserved and showed a good abundance and a wide diversity. (See range chart in Text Fig. 31.) The core catcher sample (99A/12/cc) was barren.

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 is the most common species and is found throughout the sampled material. Cyclagelosphaera margereli NOEL 1965, Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968 and Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 are also consistently present. Apart from the persistent occurrence of these species the sampled section is characterised



Text Fig. 31 Stratigraphic Distribution of Calcareous Nannofossils in the D.S.D.P. Hole 99A.

by four phases of new species influxes. The first phase, in Sample 99A/14/1/120-121, sees the appearance for the first time in this section of Diazomatolithus lehmani NOEL 1965, Watznaueria biporta BUKRY 1969 and Zygodiscus noeli (ROOD, HAY & BARNARD 1971) n. comb. although these species are recorded earlier in the Jurassic in other studied sections. The second phase (Sample 99A/11/2/122-123) is strongly marked by the first occurrence of Conusphaera mexicana TREJO 1969, Cruciellipsis cuvillieri (MANIVIT 1966) THIERSTEIN 1971, Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971, Nannoconus steinmanni KAMPTNER 1931, Nannoconus truitti BRONNIMANN 1955 and Parhabdololithus embergeri (NOEL 1958) STRADNER 1963, species which are normally associated with the Lower Cretaceous. The third phase (99A/11/2/40-41) is marked by the presence of three species of Discoaster which can only be assumed to be Neogene contaminants. In the fourth phase (Sample 99A/8/1/145-146) Markalius inversus (DEFLANDRE 1954) BRAMLETTE & MARTINI 1964 and Micrantholithus holschulzi (REINHARDT 1966) THIERSTEIN 1971, which are also Lower Cretaceous species, are recorded for the first time.

From the calcareous nannofossil assemblages the following can be deduced:

1. Samples 99A/14/2/110 - 99A/14/1/120 contain calcareous nannofossil assemblages with a low species diversity and many of the species are long ranging forms. The absence of Ethmorhabdus gallicus NOEL 1965, Polypodorhabdus madingleyensis BLACK 1968 and Stephanolithion bigoti DEFLANDRE 1939 (Callovian - Oxfordian species) and the absence of the typically Lower Cretaceous forms which appear further up the core suggests, albeit on negative evidence, a Kimmeridgian age for this interval. However, the presence of Schizosphaerella punctulata DEFLANDRE

& DANGEARD 1938 in Sample 99A/14/2/39 suggests a possible Oxfordian influence since this species is not normally found very much above the Oxfordian.

2. No samples were available from Core 13 and the one sample from Core 12 (core catcher) was barren.
3. After this break in the sampling the assemblages are markedly different. In Samples 99A/11/2/122 - 99A/8/1/91 species whose first occurrences have been variously assigned to Middle Kimmeridgian, Tithonian, Berriasian and Valanginian ages are found. An age determination for this interval is difficult since the influence of the break in sampling on the pattern of species first occurrences is not known. For example, in Sample 99A/11/2/122 Conusphaera mexicana, whose first occurrence is considered by THIERSTEIN (1976) as being at the base of the Tithonian, is found for the first time at the same level as the first appearance of Nannoconus steinmanni and Parhabdolithus embergeri. BRONNIMANN (1955) and BARNARD and HAY (1974) considered these two biohorizons as indicative of the base of the Cretaceous and the Middle Kimmeridgian respectively.

The presence in Sample 99A/11/2/40 of three species of Discoaster clearly indicates contamination in the core and confirms the report by shipboard scientists of Tertiary contamination during drilling. This leads to speculation that some of the typically Lower Cretaceous forms might also be contaminants. This is thought to be unlikely since they are consistently found throughout the top half of the section in contrast to the species of Discoaster which are only found in one sample. Also, evidence in the literature on other microfossils from Hole 99A confirms

a strong Lower Cretaceous influence in the assemblages. (HABIB - dinoflagellates; LEHMANN - thin sections; LUTERBACHER - foraminifera.)

A summary of the age assignments for Site 99A obtained by other workers using microfossils is given in Text Fig. 32.

6.3.2. Deep Sea Drilling Project Site 100

32 samples from Hole 100 were processed and examined for their calcareous nannofossil assemblages. They generally contained a good variety and abundance of quite well preserved calcareous nannofossils whose stratigraphic distribution is shown in Text Fig. 33. The assemblages are dominated by Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 and some samples contain abundant specimens of Cyclagelosphaera margereli NOEL 1965 and Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968. Tetralithus gothicus DEFLANDRE 1959 was particularly common in the lower part of the section (Cores 8 - 10). The remaining species are usually "rare" and occur sporadically.

There are no significant species first appearances in this hole. In fact, the only biostratigraphically important horizon is the last occurrence of Stephanolithion bigoti DEFLANDRE 1939 which can be seen in the range chart (Text Fig. 33) to be in Sample 100/5/2/76-77. This horizon is considered by many authors to be at the Oxfordian/Kimmeridgian boundary. The presence in the interval below Sample 100/5/2/76-77 of Ethmorhabdus gallicus NOEL 1965 and Hexapodorhabdus cuvilleiri NOEL 1963 is consistent with an Oxfordian age assignment for this part of the section. Also, reduced species diversity, such as is found in the upper part of this section, is typical of Kimmeridgian assemblages.

Again, as in Hole 99A, the age determinations for this hole by other workers using foraminifera, thin sections, dinoflagellates and

DSDP SITE 99A	CALCAREOUS NANNOFOSSILS Bukry	CALCAREOUS NANNOFOSSILS Wilcoxon	DINOFLAG-ELLATES Habib	FORAMINIFERA Luterbacher	THIN SECTIONS Lehmann
Core 8	Lower Cretaceous (Valanginian)	Tithonian	Valanginian	Valanginian	
Core 9				Valanginian to Tithonian	Early Cretaceous
Core 10	Tithonian to Kimmeridgian				
Core 11					
Core 12					
Core 13	Upper Jurassic	Kimmeridgian or Oxfordian	Kimmeridgian or Oxfordian		
Core 14					
DSDP SITE 100	CALCAREOUS NANNOFOSSILS Bukry	CALCAREOUS NANNOFOSSILS Wilcoxon	DINOFLAG-ELLATES Habib	FORAMINIFERA Luterbacher	THIN SECTIONS Lehmann
Core 1	Valanginian	Early Cretaceous or Late Jurassic	No determination	Berriasian or Tithonian	
Core 2		Kimmeridgian or Oxfordian		Kimmeridgian to Oxfordian	Tithonian to Kimmeridgian
Core 3			Kimmeridgian to Callovian		
Core 4					
Core 5					
Core 6					
Core 7	Kimmeridgian to Oxfordian	Callovian			
Core 8					
Core 9					
Core 10	B A S A L T				
Core 11					
Core 12					
Core 13					

Text Fig. 32 Stage Determinations using Microfossils for the D.S.D.P. Holes 99A and 100.

STAGE	CALCAREOUS NANNOFOSSIL ZONE	SAMPLE NUMBER	<i>H. cuvillieri</i>	<i>E. gallicus</i>	<i>S. bigoti</i>	<i>B. ellipticum</i>	<i>E. keftalrempli</i>	<i>E. britannica</i>	<i>C. margereli</i>	<i>T. gothicus</i>	<i>W. barnesae</i>	<i>S. quadriarculus</i>	<i>P. cylindricus</i>	<i>D. ignotus</i>	<i>Z. erectus</i>	<i>Z. elegans</i>	<i>Z. noeli</i>	<i>W. biporta</i>	<i>Diazomatolithus</i> sp.	<i>D. lehmani</i>	<i>D. patulus</i>	<i>S. punctulata</i>
KIMMERIDGIAN	<i>(P. madingleyensis</i> Zone)	100 2 1 100-101																				
		100 2 2 30-31																				
		100 2 2 98-99																				
		100 2 3 40-41																				
		100 2 3 103-104																				
		100 3 1 137-138																				
		100 4 1 31-32																				
		100 4 1 87-88																				
		100 4 1 140-141																				
		100 5 1 130-131																				
100 5 2 18-19																						
100 5 2 76-77																						
100 5 2 130-131																						
100 6 1 20-21																						
100 6 1 67-68																						
100 6 1 120-121																						
100 7 1 47-48																						
100 7 1 90-91																						
100 7 1 142-143																						
100 7 2 25-26																						
100 7 2 98-99																						
100 8 1 120-121																						
100 8 2 50-51																						
100 8 2 110-111																						
100 8 3 50-51																						
100 8 3 101-102																						
100 9 1 100-101																						
100 9 2 40-41																						
100 9 2 110-111																						
100 10 1 100-101																						
100 10 2 35-36																						
100 10 2 100-101																						

Abundant
Very Common
Common
Rare
Inferred

[] Abundant
 [] Very Common
 [] Common
 [] Rare
 [] Inferred

Text Fig. 33 Stratigraphic Distribution of Calcareous Nannofossils in the D.S.D.P. Hole 100.

calcareous nannofossils are somewhat confused. The various attempts are summarised in Text Fig. 32

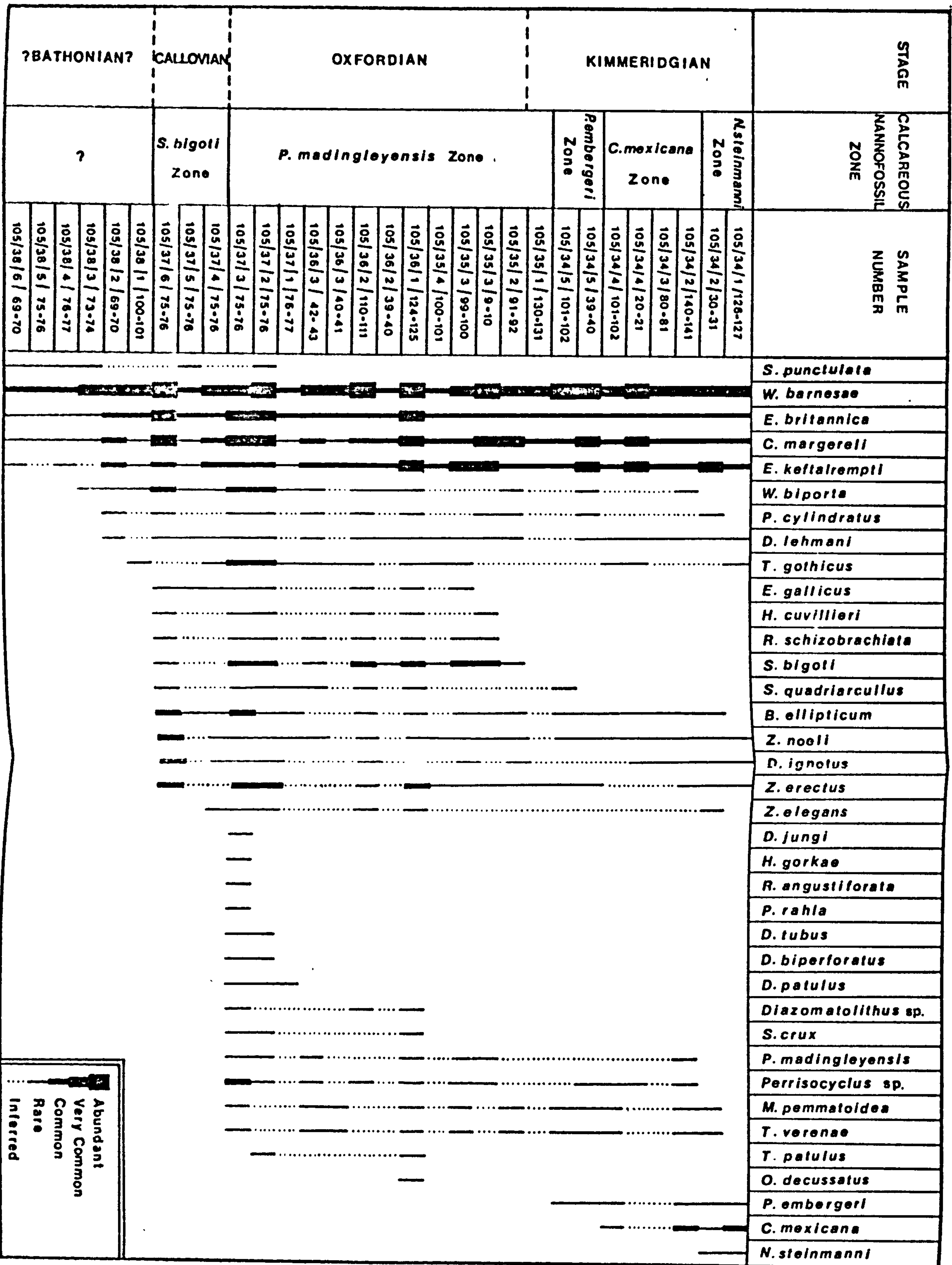
6.3.3. Deep Sea Drilling Project Site 105

30 samples were analysed from the lower part of Hole 105. They yielded very well preserved, diverse assemblages with a good abundance of calcareous nannofossils (Text Fig. 34).

The assemblages are dominated by Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 which is also found to be the most common species in Holes 99A and 100. Cyclagelosphaera margereli NOEL 1965, Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968 and Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 are very common in these assemblages. The remaining species are either fairly common or rare and some of these occur sporadically.

The range chart in Text Fig. 34 shows that there are roughly three phases of species first appearances within the section. They are each characterised by the appearance of a species which has been selected by previous authors for biostratigraphy. The first phase, in Sample 105/37/6/75-76, sees the appearance of Stephanolithion bigoti DEFLANDRE 1939; this horizon is thought to indicate a basal Callovian age (AMEZIEUX 1972; BARNARD and HAY 1974; MOSHKOVITZ and EHRLICH 1976; STRADNER 1963; THIERSTEIN 1976). The upper limit of this species is thought by these authors to be at the top of the Oxfordian. The second phase, in Sample 105/37/3/75-76, is marked by the first appearance of Polypodorhabdus madingleyensis BLACK 1968 which BARNARD and HAY (1974) find in the Middle Callovian (as Polypodorhabdus escaigi NOEL 1965) and which THIERSTEIN (1976) records at the base of the Oxfordian (also as Polypodorhabdus escaigi). The third phase sees the appearance of three

Text Fig. 34 Stratigraphic Distribution of Calcareous Nanofossils in the D.S.D.P. Hole 105.



biostratigraphically useful species at different levels. In Sample 105/34/5/101-102 Parhabdolithus embergeri (NOEL 1958) STRADNER 1963 is recorded for the first time. This horizon is used by BARNARD and HAY (1974) to indicate the Upper Kimmeridgian and is recorded in the Purbeckian by STRADNER (1963). In Sample 105/34/4/101-102 the first occurrence of Conusphaera mexicana TREJO 1969, which is thought to indicate a basal Tithonian age (THIERSTEIN 1976), is recorded. Thirdly, Nannoconus steinmanni KAMPTNER 1931 has its first appearance in Sample 105/34/2/30-31; this horizon is variously attributed to Purbeckian deposits (STRADNER 1963) and basal Berriasian aged sediment (THIERSTEIN 1976).

Finally, the range chart (Text Fig. 34) shows that the samples from Core 38 contain a low diversity of calcareous nannofossils. Only the long ranging and more dominant species such as Watznaueria barnesae are present. Following the preceding discussion which pointed out that the lowest occurrence of Stephanolithion bigoti indicates the base of the Callovian, it might be suggested that Core 38 is in Middle Jurassic, possibly Bathonian deposits. However, the absence of typically Middle Jurassic species such as Stephanolithion hexum ROOD & BARNARD 1972, Stephanolithion speciosum DEFLANDRE 1954 and Stephanolithion speciosum var. octum ROOD & BARNARD 1972 and the reduced diversity in Core 38 suggests that there may be a lithological or palaeoenvironmental control on the assemblages. No definite age assignment can be given for this part of the section.

However, the main part of the core can be quite well dated using calcareous nannofossils. The assemblages and age assignments recorded in this study appear to correlate closely with the data given by BUKRY (1972), WILCOXON (1972a, 1972b) and THIERSTEIN (1976) (see Text Fig.35).

DSDP SITE 105	APTACHI Renz	CALCAREOUS NANNOFOSSILS Bukry	CALCAREOUS NANNOFOSSILS Wilcoxon	CALCAREOUS NANNOFOSSILS Thierstein	DINOFLAG- ELLATES Habib	FORAMINIFERA Luterbacher	OSTRACODS Oertli	THIN SECTIONS Lehmann
Core 33	Tithonian to Kimmeridgian	Tithonian or Portlandian	Oxfordian	Barriasian	Barren ----- Kimmeridgian to Oxfordian	Tithonian to Kimmeridgian	Upper Jurassic	Early Berriasian or Late Tithonian
Core 34		?		Tithonian				
Core 35				Oxfordian				
Core 36								
Core 37		Kimmeridgian or Oxfordian						
Core 38					Barren	Kimmeridgian to Oxfordian		
Core 39								
Core 40								
Core 41	B A S A L T							
Core 42								
Core 43								

Text. Fig. 35 Stage Determinations using Microfossils for the D.S.D.P. Hole 105.

Comparison of the biostratigraphy obtained using calcareous nannofossils with those obtained using other microfossils is also quite good. (See Text Fig. 35.)

7. JURASSIC CALCAREOUS NANNOFOSSILS - A SYNTHESIS OF THE DATA

In the preceeding discussions of the sampled localities the calcareous nannofossil assemblages from each section have been described and their biostratigraphic significance has been briefly recorded.

The bulk of the work carried out for this study concerned the Portuguese Jurassic. The sections from Great Britain and the western North Atlantic were examined mainly for comparative purposes. The Watchet Section was analysed because it covered the lower part of the Jurassic which was not sampled in Portugal.

The lack of provincialisation in the calcareous nannofossil assemblages permits a synthesis of all this data despite the wide geographic area covered by the sampling. From such a synthesis a broad picture of the events in the calcareous nannofossil record during the Jurassic is developed.

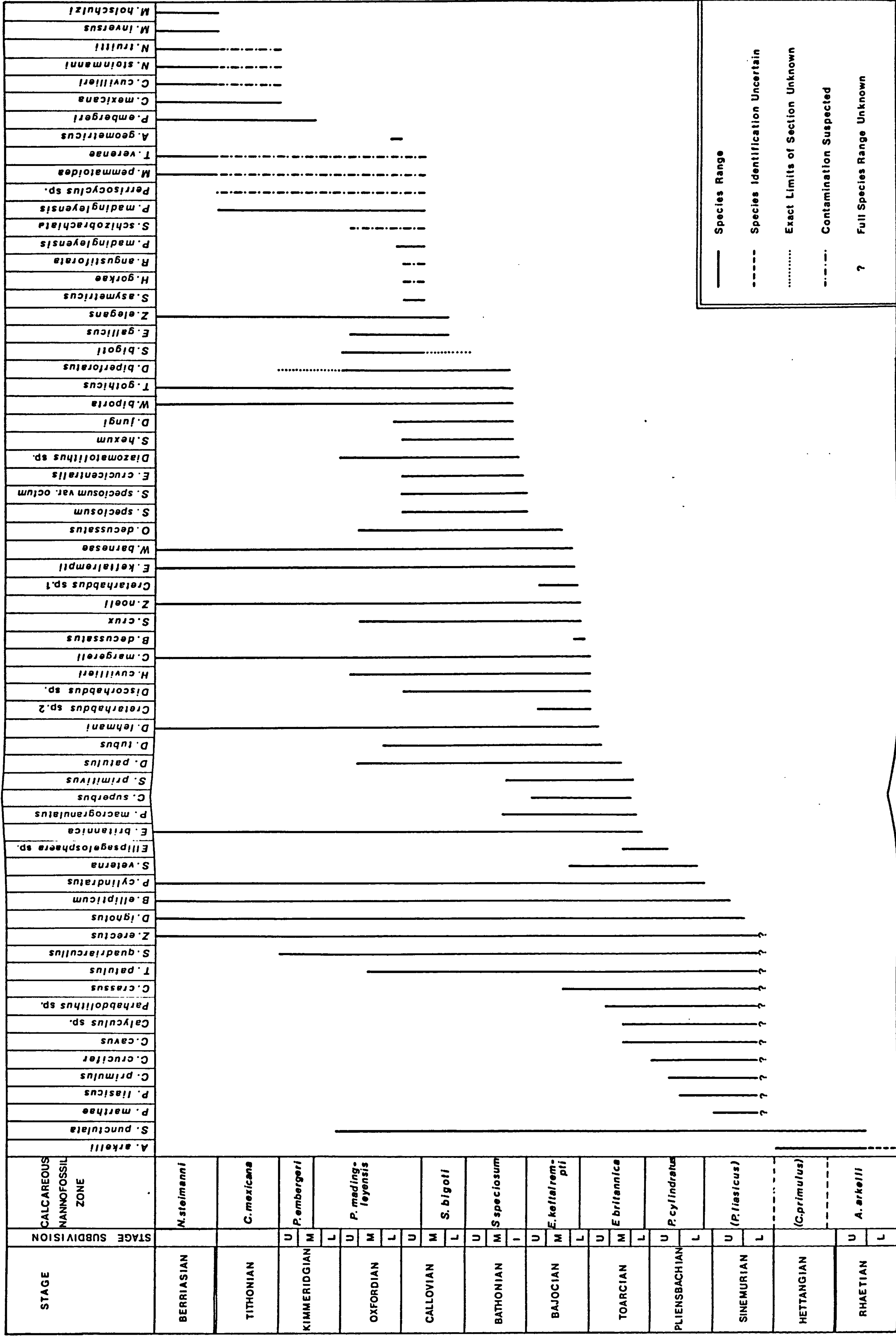
The chart in Text Fig. 36 is a summary of the ranges of all the calcareous nannofossils found in this study.

This chart shows that there are no species which occur throughout the entire Jurassic interval. There are, however, several long ranging species:-

Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938: Upper Rhaetian
to Middle Oxfordian

<u>Biscutum ellipticum</u> (GORKA 1957) GRÜN & ALLEMANN 1975	} Lower Sinemurian to the top of the Jurassic
<u>Discorhabdus ignotus</u> (GORKA 1957) PERCH-NIELSEN 1968	
<u>Staurorhabdus quadriarcullus</u> (NOEL 1965) NOEL 1973	
<u>Zygodiscus erectus</u> (DEFLANDRE 1954) MANIVIT 1971	

(The latter four species are also known in the Lower Cretaceous - TAYLOR, personal communication.)



Text Fig. 36 Generalised Stratigraphic Distribution of Jurassic Calcareous Nannofossils.

There are other species with slightly shorter ranges that are found from the Toarcian or Bajocian to the Lower Cretaceous:-

Cyclagelosphaera margereli NOEL 1965

Diazomatolithus lehmani NOEL 1965

Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968

Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968

Zygodiscus noeli (ROOD, HAY & BARNARD 1971) n. comb.

Also there are a few species in this chart whose upper limits in the sections studied here lie below the top of the Jurassic although they have been recorded in the Lower Cretaceous by other workers (TAYLOR, personal communication):-

Actinozygus geometricus (GORKA 1957). ROOD, HAY & BARNARD 1971

Ellipsagelosphaera crucicentralis MEDD 1971

Polypodorhabdus madingleyensis BLACK 1968

Staurolithites crux (DEFLANDRE 1954) CARATINI 1963

In addition, there are several species, recovered from the Deep Sea Drilling Project Sites 99A and 105, which have never been reported in sediment older than Lower Cretaceous age before:-

Cruciellipsis cuvillieri (MANIVIT 1966) THIERSTEIN 1971

Hemipodorhabdus gorkae (REINHARDT 1969) GRÜN & ALLEMANN 1975

Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971

Nannoconus truitti BRONNIMANN 1955

Perrisocyclus sp.

Retecapsa augustiforata BLACK 1971

Retecapsa schizobrachiata (GARTNER 1968) GRÜN & ALLEMANN 1975

Tubodiscus verenae THIERSTEIN 1973

The author regards their presence in the Upper Jurassic with caution, especially as they were only recovered in the Deep Sea Drilling Project cores in which down-hole contamination is a common occurrence. Calcareous nannofossils are particularly susceptible to down-hole washing and reworking because of their small size. The risk that the interpretation of a calcareous nannofossil assemblage will be confused by contamination is, therefore, very high. For this reason the recorded ranges of the species listed above are shown in a dot-dash line in the range chart (Text. Fig. 36). These species are not considered to be reliable components of the assemblages in the biostratigraphic scheme which is later developed.

Finally it remains to list the species whose first or last occurrences have been chosen as biohorizons for the calcareous nannofossil biostratigraphy:-

Annulithus arkelli RÖÖD, HAY & BARNARD 1974

Conusphaera mexicana TREJO 1969

Crucirhabdus primulus PRINS 1969 ex RÖÖD, HAY & BARNARD 1973

Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968

Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1973

Nannoconus steinmanni KAMPTNER 1931

Parabdolithus embergeri (NOEL 1958) STRADNER 1963

Parabdolithus marthae DEFLANDRE 1954

Parabdolithus liasicus DEFLANDRE 1952

Podorhabdus cylindratus NOEL 1965

Polypodorhabdus madingleyensis BLACK 1968

Stephanolithion bigoti DEFLANDRE 1939

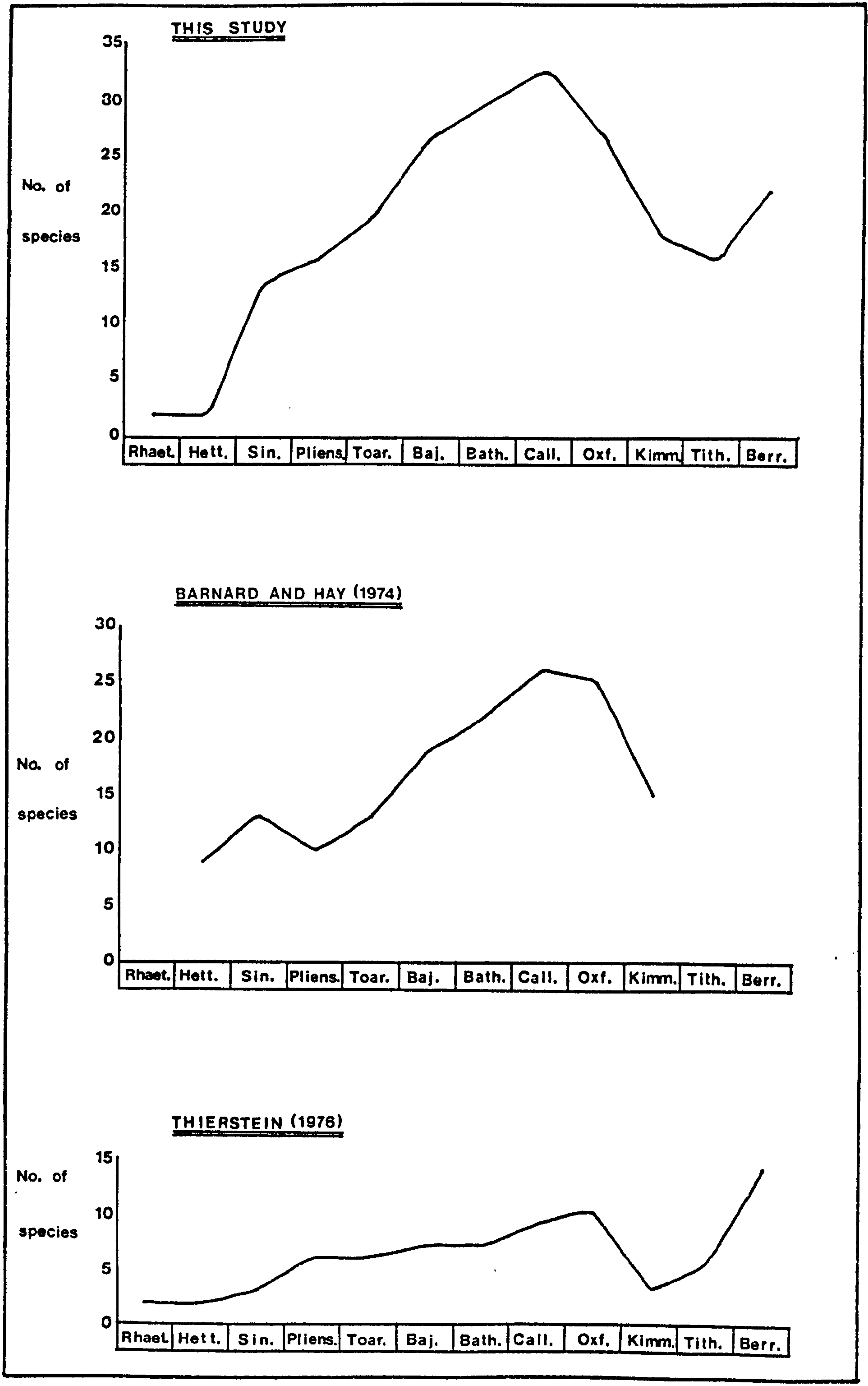
Stephanolithion speciosum DEFLANDRE 1954

The most important observations that should be made with regard to the range chart in Text Fig. 36 relate to species diversity, that is the number of different species recorded in an assemblage. The range chart demonstrates quite clearly that there is a dramatic increase in species diversity during the Jurassic. This is further demonstrated in the graph in Text Fig. 37 (Graph 1). Here, it can be seen that the increase in diversity does not follow a smooth curve, but rather, is subject to some fluctuation.

The number of species in assemblages of Rhaetian and Hettangian age is very low, but species diversity increases rapidly to reach a peak of 33 species during the Callovian. There is a slight decrease in diversity during the Oxfordian which becomes more marked in the Kimmeridgian. The downward trend in species diversity is reversed during the Tithonian so that by the beginning of the Lower Cretaceous the number of species is again increasing.

In Text Fig. 37 there are two other graphs; these illustrate the changes in species diversity recorded by BARNARD and HAY (1974) and THIERSTEIN (1976). The data to complete these graphs was extracted from the range charts of the authors. In both studies species diversity was found to increase during the Jurassic although the actual number of species recorded varied considerably. In his range chart THIERSTEIN (1976, Fig. 7), for example showed only those species which he considered to be biostratigraphically useful.

The data of BARNARD and HAY (Graph 2) demonstrates that they recorded an increase in species diversity from the Hettangian to the Sinemurian and a slight decrease during the Pliensbachian. Following this, species diversity was found to increase steadily and to reach a peak during the Callovian. A Callovian peak accords with the data



Text Fig.37 Species Diversity Fluctuations during the Jurassic.

obtained in this study as shown in Graph 1. The decrease in species diversity during the Kimmeridgian shown in Graph 1 was also recorded by BARNARD and HAY.

The data of THIERSTEIN (Graph 3) echoes the trends recorded in this study except that his peak in species diversity is not recorded until the Oxfordian. Also, THIERSTEIN recorded the final increase in diversity in the Tithonian while it was here not noted until the Lower Cretaceous.

The fluctuations in species diversity during the Jurassic have been attributed by BARNARD and HAY (1974) to major changes in facies. For example, the Callovian/Oxfordian peak in species diversity was related to the widespread clay deposition which replaced the shallower water Middle Jurassic deposits in England. Similarly, the decrease in species diversity at the top of the Jurassic was related to shallow water, turbid conditions which prevailed during the Kimmeridgian.

While the author agrees that facies has an important influence on species diversity it is noted that the comparison between facies and species diversity is only locally applicable. In this synthesis of data from a wide geographic area such inferences are not possible.

The general increase in species diversity which is here recorded for the Jurassic interval is regarded as being a feature of the overall development of the calcareous nannoplankton. This increase which is relatively unaffected by local environmental changes, continues to be observed during the Cretaceous.

8. A REVIEW OF PREVIOUS WORK ON JURASSIC CALCAREOUS NANNOFOSSILS

Previous work on Jurassic calcareous nannofossils can be subdivided into that which is primarily taxonomic in nature and that which concentrates on biostratigraphy. The early publications were mostly concerned with taxonomy (BRONNIMANN 1955; DEFLANDRE 1939; DEFLANDRE and DANGEARD 1938; DEFLANDRE and FERT 1954; LEZAUD 1968; MARESCH 1966; NOEL 1956, 1958, 1965a, 1965b, 1970; REINHARDT 1964, 1966, 1969; STRADNER 1961; TREJO 1969) although some more recent papers have also considered detailed aspects of taxonomy (GRÜN, PRINS and ZWEILI 1974; KEUPP 1975, 1976a, 1976b, 1977; MEDD 1971; NOCERA 1971; NOEL 1973; REINHARDT 1970, 1971; ROOD and BARNARD 1972; ROOD, HAY and BARNARD 1971, 1973; WILCOXON 1972a; WISE and WIND 1976). These lists only include publications which have considered Jurassic calcareous nannofossils; they do not include other taxonomic papers which are concerned with Cretaceous assemblages but which describe some of the species recorded in this study (BLACK 1964, 1968, 1971, 1972, 1973; BUKRY 1969; FORCHHEIMER 1968, 1970, 1972; GARTNER 1968; GRÜN and ALLEMANN 1975; HILL 1976; MANIVIT 1965, 1971; NOEL 1970; PERCH-NIELSEN 1968; ROTH and THIERSTEIN 1972; SHAFIK and STRADNER 1971; STOVER 1966; for example).

This literature provides a full background of information which enables individual workers in a wide geographical area to contribute towards developing a useful biostratigraphic scheme by means of the stratigraphic correlation of the species which are common to each area.

The biostratigraphic value of calcareous nannofossils in the Tertiary and Cretaceous has been clearly demonstrated (BUKRY and BRAMLETTE 1970; HAY et al 1967; MANIVIT 1971; MARTINI and WORSLEY 1970; ROTH 1970, 1973; THIERSTEIN 1971, 1973, 1976). Recently, several papers describing

zonal schemes for the Jurassic have been published (AMEZIEUX 1972; BALDI-BEKE 1962; BARNARD and HAY 1974; BRONNIMANN 1955; GEEL 1966; HAMILTON 1977; MOSHKOVITZ and EHRLICH 1976; PRINS 1969; STRADNER 1963; THIERSTEIN 1975, 1976; WORSLEY 1971). These schemes are illustrated in Text Fig. 38 and in the following section the application of each one to the results obtained in this work is considered.

PRINS (1969), in a study of more than 500 Lower Jurassic samples from England, France and West Germany, proposed four zones and five subzones for the Rhaetian to Middle Lias interval. His zones were distinguished by the first occurrences of certain species but some of his subzones (Crepidolithus cavus Subzone, Crepidolithus crassus Subzone, Parhabdolithus liasicus Subzone) are identified on the basis of the abundance of the marker species and not their ranges. In this study the author has found that species abundance is an inconsistent factor which is unsuitable for calcareous nannofossil biostratigraphy. PRINS' scheme cannot really be applied satisfactorily to the data obtained in this study. His Crucirhabdus primulus Zone (Rhaetian - Hettangian) is not applicable in the studied areas since Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 is not here recorded until the Sinemurian Stage. His Parhabdolithus Zone (Sinemurian), subdivided into the Parhabdolithus liasicus Subzone and the Parhabdolithus marthae Subzone, again cannot be applied because the ranges of the marker species in Portugal differ from those shown by PRINS (PRINS 1969, Table 1). Similarly, in his Crepidolithus Zone the ranges of the subzone marker species, Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973 and Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965, do not strictly correlate with the ranges of these species in Portugal. Finally, the marker species for the uppermost zone, Striatococcus opacus PRINS 1969, is not recorded in this study.

STAGE	AMEZIEUX (1972)	BALDI-BEKE (1962)	BARNARD AND HAY (1974)	BRONNIMANN (1955)	GEEL (1966)	HAMILTON (1977)	MOSHKOVITZ AND EHRLICH (1976)	PRINS (1969)	STRADNER (1963)	THIERSTEIN (1976)	WORSLEY (1971)
Berriasian		N. steinmanni		N. steinmanni	N. steinmanni				N. steinmanni	base N. steinmanni	Equadriscerratus & D. rectus
Tithonian										base C. mexicana	N. steinmanni
Kimmeridgian			P. embergeri W. communis							top S. bigoti	Pembergeri
Oxfordian	S. bigoti		V. stradneri A. geometricus D. dorsetense				S. bigoti			base P. escaigi	
Callovian			D. jungi P. rahla P. escaigi S. bigoti S. hexum S. octum						Bigoti	base S. bigoti	
Bathonian	S. speciosum & Ellipsagelosphaera sp.		D. lehmani S. speciosum				S. speciosum		Decorus	base S. speciosum	
Bajocian			D. tubus				H. magharensis			base W. communis	
Toarcian			P. cylindricus			D. patulus		Striatococcus		base P. cylindricus	
Pliensbachian			C. crassus P. dubia P. liasicus P. marthae C. primulus A. arkelli			P. vetera P. cylindricus B. ellipticum		Crepidolithus	Opacus	base C. crassus	
Sinemurian	Parahbdolithus							Parahbdolithus	Liasicus	base P. liasicus	
Hettangian	C. primulus							Crucirhabdus			
Rhaetian										base C. primulus	

Text Fig. 38 Calcareous Nannofossil Biostratigraphic Schemes for the Jurassic.

HAMILTON (1977) tentatively proposed a zonal scheme for the Sinemurian to Toarcian interval from a study of the calcareous nannofossils of the Lower Jurassic part of the Brenha Road Section in Portugal. Four zones and five subzones were defined using the first or last occurrences of selected species. This scheme is of limited value because it was developed from the study of only one section; its application has not been tested in any other geographical areas. Some revision of the scheme will be discussed in the following chapter. The contribution does, however, provide some more information about a hitherto little known part of the calcareous nannofossil record.

MOSHKOVITZ and EHRLICH (1976) studied the Bajocian to Oxfordian interval in Israel and North Sinai and proposed three calcareous nannofossil zones. Their Stephanolithion speciosum Zone and their Stephanolithion bigoti Zone correspond stratigraphically with zones of the same name described by other workers (AMEZIEUX 1972; STRADNER 1963; THIERSTEIN 1976). The choice of Hexalithus magharensis MOSHKOVITZ & EHRLICH 1976 as the marker species for their third zone does not permit global correlation at this stage since the species has not been recorded elsewhere. Also, the sections described by these authors are not well known in terms of the established stage and zone system so that correlation with other regions is tentative.

WORSLEY (1971) worked on the Jurassic-Cretaceous boundary interval in sediments from the western Atlantic and proposed two zones for the uppermost Jurassic part. His study involved the examination of only seven samples from the Kimmeridgian-Cenomanian interval and the precise age of the samples was not known below the stage level. WORSLEY's zones can only be loosely applied to the data obtained in this study.

THIERSTEIN (1975) also worked on the Jurassic-Cretaceous boundary. In a study of three sections from the Tithonian to the Valanginian of France, the western Atlantic and the western Pacific he revised his scheme for the Lower Cretaceous (THIERSTEIN 1973). He also formerly defined the Conusphaera mexicana Zone in the early to late Tithonian interval and described his Berriasian Nannoconus colomi Zone. (Nannoconus colomi (de Lapparent 1931) KAMPTNER 1938 as used by THIERSTEIN is regarded as synonymous with Nannoconus steinmanni KAMPTNER 1931.) These zones can be applied to the data recorded in this study.

BRONNIMANN (1955) examined nannoconids, calpionellids and other microfossils from the Upper Jurassic and Lower Cretaceous in Cuba. He described three Nannoconus Zones, of which the oldest was the Nannoconus steinmanni Zone. The pre-Cretaceous history of Nannoconus steinmanni KAMPTNER 1931 is not known in Cuba (BRONNIMANN 1955, Chart 1, Page 32) and BRONNIMANN considered the base of the Nannoconus steinmanni Zone to be at the base of the Lower Cretaceous. This age assignment is followed in this work.

BALDI-BEKE (1962) carried out a stratigraphic study of Nannoconus in the uppermost Tithonian and Lower Cretaceous sediments of Hungary. Three zones were proposed and the oldest of these was again the Nannoconus steinmanni Zone. In Hungary the lowest occurrence of the marker species was in the Upper Tithonian.

GEEL (1966) worked on nannoconids and tintinnids from Upper Jurassic to Lower Cretaceous sediments in Spain and applied the Nannoconus zones of BRONNIMANN and BALDI-BEKE. His Nannoconus steinmanni Zone also has its lower limit in the Upper Tithonian. GEEL concluded that although the ages of the zones are not clearly known, the succession

of the Nannoconus Zones (Nannoconus steinmanni Zone, Nannoconus kamptneri Zone and Nannoconus truitti Zone) is established in Hungary, Cuba and south-east Spain as being the same.

The eight preceeding schemes all considered small parts of the Jurassic. The remaining four biostratigraphic schemes were concerned with the whole of the Jurassic.

STRADNER (1963) made an early attempt to apply calcareous nannofossils to Mesozoic stratigraphy and he proposed five associations for the Jurassic interval. The assemblages described by STRADNER are, in the light of present day knowledge, very limited and some of the species names introduced by him have not been adopted by later workers (Coccolithus opacus STRADNER 1961 for example). Detailed comparisons with other studies are therefore rather limited. Also, the absence of any description of sample location excludes this study from correlatory analyses. STRADNER's Lower and Middle Jurassic subdivisions, the Liasicus, Opacus and Decorus Associations, can be applied to the data obtained in this study in a limited way. His Upper Jurassic Bigoti and Nannoconus steinmanni Associations, however, are useful.

AMEZIEUX (1972) studied the Hettangian to Lower Kimmeridgian interval in the Paris Basin and the Aquitanian Basin. He subdivided the interval into five zones and nine subzones and followed PRINS' (1969) scheme where possible (Crucirhabdus primulus Zone and Parhabdolithus Zone). He also used the Crepidolithus Zone of PRINS but defined the lower of the two subzones with a new species, Crepidolithus cancer. This species is nowhere defined by AMEZIEUX and it might be that a printing error has altered the name from Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973.

Application of AMEZIEUX's scheme to the data obtained from Portugal, Great Britain and the western North Atlantic produces a fairly satisfactory result. The Hettangian Crucirhabdus primulus Zone cannot really be applied due to the poor diversity of calcareous nannofossils in the assemblages from the Watchet Section. The Sinemurian Parhabdolithus Zone was subdivided into two subzones on the relative abundance of Parhabdolithus liasicus DEFLANDRE 1952 and Parhabdolithus marthae DEFLANDRE 1954. The latter of the two subzones can be used but only in terms of the overall range of the marker species and not on its abundance. In Portugal Parhabdolithus liasicus is found above the top of the Sinemurian so that AMEZIEUX's second zone cannot strictly be applied. His Pliensbachian-Lower Bajocian Crepidolithus Zone was also subdivided on the basis of the relative abundance of the marker species, Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 and Crepidolithus cancer AMEZIEUX 1972. The upper limit of Crepidolithus crassus in Portugal does not correspond with AMEZIEUX's data and Crepidolithus cancer is not here recognised. AMEZIEUX's scheme is more useful in the Middle and Upper Jurassic. For example, his Stephanolithion speciosum Zone can be applied although he recorded the upper limit of the marker species in the Lower Oxfordian whilst in Portugal it is found at the top of the Callovian. Similarly, his Stephanolithion bigoti Zone can be used although he found the upper limit of Stephanolithion bigoti DEFLANDRE 1939 in the Kimmeridgian while it is here recorded at the top of the Oxfordian.

BARNARD and HAY (1974) examined the Hettangian to Kimmeridgian interval from sections in southern England and North France and described 22 zones. Application of their scheme to the results of this study reveals the following:-

Annulithus arkelli Zone (Hettangian)

Good correlation

Crucirhabdus primulus Zone (Lower Sinemurian)

Parhabdolithus marthae Zone (Lower Sinemurian)

Parhabdolithus liasicus Zone (Lower Sinemurian)

These zones cannot be used due to a break in sampling in this interval.

Paleopontosphaera dubia Zone (Upper Sinemurian)

The marker species, Paleopontosphaera dubia NOEL 1965 is here considered to be synonymous with Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975. The lowest occurrences of the marker species can be correlated at the stage level but are not found in the same ammonite zone.

Crepidolithus crassus Zone (Upper Sinemurian-Lower Pliensbachian)

The lowest occurrence surfaces cannot be correlated since in Portugal the species first appears in the Lower Sinemurian.

Podorhabdus cylindratus Zone (Lower Pliensbachian-Toarcian)

The lowest occurrence surfaces of the marker species, Podorhabdus cylindratus NOEL 1965, are not found in the same ammonite zone although they both lie within the Lower Pliensbachian.

Discorhabdus tubus Zone (Upper Toarcian-Lower Bajocian)

Good correlation.

Stephanolithion speciosum Zone (Bajocian-Lower Bathonian)

This zone cannot be applied in Portugal due to the later appearance here of the marker species, Stephanolithion speciosum DEFLANDRE 1954.

Diazomatolithus lehmani Zone (Bathonian)

In their range chart (Fig. 2) BARNARD and HAY recorded the lowest

occurrence of the marker species in the Lower Bajocian, at the same level as that for Stephanolithion speciosum. The zone should not be placed in the Lower Bathonian as is shown in their coccolith zone column since its definition states that it extends "from the lowest occurrence of Diazomatolithus lehmani NOEL 1965 to the lowest occurrence of Stephanolithion speciosum var. octum ROOD & BARNARD 1972". Therefore, the zone cannot strictly be included.

Stephanolithion speciosum var. octum Zone (Upper Bathonian)

Again, the range of the marker species in BARNARD and HAY's chart (Fig. 2) does not correspond to the coccolith zone column. The lowest occurrence of Stephanolithion speciosum var. octum is recorded in the Middle Bathonian but the base of the zone, which is defined by the lowest occurrence of the marker species, is drawn in the Upper Bathonian. Nevertheless, the zone cannot be used in Portugal since the marker species is first recorded there in the Lower Bathonian.

Stephanolithion hexum Zone (Lower Callovian)

Correlation is not good since Stephanolithion hexum ROOD & BARNARD 1972 is found in the Lower Bathonian in Portugal

Stephanolithion bigoti Zone (Lower Callovian)

Correlation is quite good. .

Polypodorhabdus escaigi Zone (Middle Callovian)

The marker species as used by BARNARD and HAY is regarded as synonymous with Polypodorhabdus madingleyensis BLACK 1968.

Correlation is quite good.

Podorhabdus rahla Zone (Middle Callovian)

Correlation is again quite good although this species is very rare and may not be a reliable stratigraphic indicator.

Discorhabdus jungi Zone (Upper Callovian)

In Portugal Discorhabdus jungi NOEL 1965 is first found in the Lower Bathonian so this zone cannot be used.

Diadozygus dorsetense Zone (Lower Oxfordian)

The marker species for this zone is not recorded in the studied sections.

Actinozygus geometricus Zone (Lower Oxfordian)

The lowest occurrence of Actinozygus geometricus (GORKA 1957) ROOD, HAY & BARNARD 1971 in the studied sections corresponds to BARNARD and HAY's results but the author considers that the species is too small, fragile and rare to be reliable for biostratigraphic purposes.

Vekshinella stradneri Zone (Middle-Upper Oxfordian)

This zone, whose base is marked by the lowest occurrence of Vekshinella stradneri ROOD, HAY & BARNARD 1971, here considered as synonymous with Stauroolithites crux (DEFLANDRE 1954) CARATINI 1963, cannot be used in this study since in Portugal the zonal marker species is first recorded in the Lower Bajocian.

Watznaueria communis Zone (Lower-Middle Kimmeridgian)

This zone, whose limits are defined as being from the highest appearance of Stephanolithion bigoti DEFLANDRE 1939 to the lowest occurrence of Parhabdolithus embergeri (NOEL 1958) STRADNER 1963, can be used in this study. However, the lower boundary of this zone is incorrectly drawn since the last appearance of Stephanolithion bigoti is at the top of the Oxfordian but the zone boundary is drawn in the Lower Kimmeridgian.

Parhabdolithus embergeri Zone (Upper Kimmeridgian)

The lowest occurrence of the marker species, Parhabdolithus embergeri, is thought to be in the Middle Kimmeridgian in the western North Atlantic. However, the stratigraphic control on the Deep Sea Drilling Project cores is not good and correlation of this type is necessarily tentative.

Whilst BARNARD and HAY's scheme can be applied in part to the results obtained from this study, it is clear that, in an attempt to produce a detailed and, therefore, potentially more useful biostratigraphy, the authors have selected zonal marker species which are sometimes rare and may not be well known in other areas or by other workers. They have, it seems, selected poorly established biohorizons in order to create a biostratigraphic event. The result is a scheme which is too detailed to be of widespread use at this stage in our knowledge of the distribution of Jurassic calcareous nannofossils and also perhaps at this early stage in the overall development of the group.

Finally, THIERSTEIN (1976) attempted to summarise the results from:

1. The literature on Mesozoic calcareous nannofossil biostratigraphy.
2. The publications on the taxonomic aspects of these fossils.
3. His work on 100 fossiliferous samples from England, Poland, South Germany, France, Switzerland and Deep Sea Drilling Project sites 99, 100, 105 and 261.

He described a scheme in which there are ten biohorizons for the whole Jurassic which are identified by the lowest and highest occurrences of certain species. The selection of these species as biostratigraphic markers was based on:

1. Distinct first (or last) occurrence, established and correlated in as many sections as possible.
2. Ease of identification in the light microscope.
3. Need for an event in a certain stratigraphic interval.

An attempt to apply THIERSTEIN's scheme to the data obtained in this study reveals the following:

Base of Crucirhabdus primulus (Rhaetian)

This species is not recorded in the Watchet Section (Rhaetian-Hettangian).

Base of Parhabdolithus liasicus (Sinemurian)

The full range of this species is not known in the studied sections because of a lack of samples covering the Lower Sinemurian interval.

Base of Crepidolithus crassus (Lower Pliensbachian)

Correlation is not good since in Portugal this species is found in the Lower Sinemurian.

Base of Podorhabdus cylindratus (Upper Pliensbachian)

Correlation is again not possible since in Portugal the base of this species is in the Lower Pliensbachian.

Base of Watznaueria communis (Bajocian)

(The species is here considered synonymous with Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968.) Again correlation is not good because of the earlier appearance of the species in Portugal at the bottom of the Toarcian.

Base of Stephanolithion speciosum (Bathonian)

Good correlation.

Base of Stephanolithion bigoti (Callovian)

Good correlation.

Base of Polypodorhabdus escaigi (Oxfordian)

The species as figured by THIERSTEIN (1976, Plate 2) is considered to be synonymous with Polypodorhabdus madingleyensis BLACK 1968. Correlation is not very good because the species is recorded in the Upper Callovian in Skye.

Top of Stephanolithion bigoti (Top of Oxfordian)

Good correlation.

Base of Conusphaera mexicana (Tithonian)

This biohorizon has been applied to the western North Atlantic sections studied here. THIERSTEIN found the species in French sections but it has not yet been recorded in Great Britain.

(MEDD, personal communication.)

Base of Nannoconus colomi (Berriasian)

Nannoconus colomi (de Lapparent 1931) KAMPTNER 1938, as illustrated by THIERSTEIN (Plate 2, Fig. 28) is here regarded as synonymous with Nannoconus steinmanni KAMPTNER 1931. The biohorizon has been applied in the western North Atlantic sections.

It is clear that THIERSTEIN's scheme can be applied to the results of this study more satisfactorily in the Bathonian to Lower Cretaceous interval than in the Rhaetian and Lower Jurassic. Some modifications to the lower part of this scheme will be discussed in the following chapter. The author regards THIERSTEIN's scheme as appropriate for the degree of zonal sophistication that is attainable with calcareous nannofossils in Jurassic biostratigraphy at this stage. The model can be easily adapted if more detailed biostratigraphy becomes possible as the result of further study.

9. BIOSTRATIGRAPHIC CLASSIFICATION

The purpose of biostratigraphic classification is to organise rock strata systematically into named units based on their fossil content, without reference to lithology or inferred environment. The International Stratigraphic Guide (HEDBERG 1975) stated that "a biostratigraphic unit may be considered to be present only within the observed limits of occurrence of the palaeontologic feature on which it is based". The Guide recommended the use of the term Biozone for a biostratigraphic unit and described four main types of biozones which result from the different ways in which strata can be zoned.

1. Assemblage Zone: A group of strata characterised by a distinctive natural assemblage of all the forms present or of the forms present of a certain kind.
2. Range Zone: A group of strata representing the stratigraphic range of some selected element of the total assemblage of fossil forms present. The word range implies extent in both vertical and horizontal directions. In this group there are four subdivisions:-
 - a) Taxon Range Zone - The body of strata representing the total range of occurrence (horizontal and vertical) of specimens of a particular taxon (species, genus or family).
 - b) Concurrent Range Zone - The concurrent or coincident parts of the range zones of two or more specified taxons selected from among the total forms contained in a sequence of strata.
 - c) Oppel Zone - Largely similar to the Concurrent Range Zone but it relaxes the strict interpretation to allow supplementary use of

biostratigraphic criteria other than range occurrence that are thought to be useful in demonstrating time equivalence.

d) Lineage Zone - A type of Range Zone consisting of the body of strata containing specimens representing a segment of an evolutionary or developmental line or trend.

3. Acme Zone: A group of strata based on the abundance or development of certain forms regardless of either association or range. This type is usually based on the maximum abundance or frequency of occurrence of some species, genus or other taxon but not its total range.

4. Interval Zone: The stratigraphic interval between two biohorizons, which are surfaces of biostratigraphic change or of distinctive character. Such a zone is not itself the range zone of any taxon and it may contain no particularly distinctive biostratigraphic assemblage or feature.

The International Stratigraphic Guide noted that the different types of biozone are useful in different circumstances and emphasized that it is most important for workers to describe the type of zone which they have used.

In the past, Jurassic calcareous nannofossil biostratigraphy has been developed using a variety of the methods described above. BALKI-BEKE (1962), BRONNIMANN (1955) and GEEL (1966) subdivided the Jurassic-Cretaceous boundary interval using *Nannoconus* assemblage zones. This type of zone was also used by MOSHKOVITZ and EHRLICH (1976) and STRADNER (1963). AMEZIEUX (1972) applied a combination of three zone types, the Range Zone, the Acme Zone and the Interval Zone and PRINS (1969)

used a combination of the Acme Zone and the Interval Zone in his work. However, the most commonly used type of zone has been the Interval Zone (BARNARD and HAY 1974; HAMILTON 1977; THIERSTEIN 1975; WORSLEY 1971). Finally, THIERSTEIN (1976) has developed a Mesozoic biostratigraphy for calcareous nannofossils using only biohorizons with no zones.

BUKRY (1971) stated that "for zones to be most widely and consistently recognised, relative abundances and first and last occurrences of the spectrum of species present in a natural zonal assemblage should take precedence over the range of any given single species. In this way, anomalies in species distribution caused by reworking, dissolution and geographic exclusion will not have a debilitating effect on the usefulness of zones". Here BUKRY is effectively advocating the use of a combination of all the four types of zones for calcareous nannofossil biostratigraphy.

For Jurassic calcareous nannofossil biostratigraphy the author regards the Assemblage Zone as unsuitable in detailed work because at this early stage in the overall development of the group the calcareous nannofossils are not yet well enough established into distinct assemblages. However, the author follows BUKRY (1971) in recommending the inclusion of a list of the species present in each zone to minimise the effects of preservation and palaeoenvironmental factors.

The Range Zone has a similarly limited application because, in the Jurassic, species are not sufficiently restricted and, at this stage, are not known well enough to be of value in detailed work.

The third type, the Acme Zone, is also regarded as unsuitable for calcareous nannofossils. There are two reasons for this. Firstly, the abundance of calcareous nannofossils in an assemblage is strongly influenced by the state of preservation of the assemblage and by

palaeoenvironmental factors. The final chapter (Chapter 11) of this paper clearly demonstrates that the original calcareous nannoplankton assemblage can be highly altered by dissolution, calcium carbonate overgrowth and by palaeoenvironmental phenomena. Secondly, species abundance is very difficult to record because of the small size and great abundance of calcareous nannofossils in a single smear slide. Also, species abundance may vary according to the methods used by different workers, as is discussed in the chapter on preparation techniques (Chapter 2).

The remaining type of zone, the Interval Zone, has proved to be the most suitable for biostratigraphic work with Jurassic calcareous nannofossils and has been used in this study.

The scheme, proposed in the next chapter and illustrated in Text Fig. 36 was developed on the basis of the results obtained in this study with some consideration of the data available in relevant literature. The limits of each biozone, that is the biohorizons, are defined in this study by the first occurrences of selected species. In addition, a list of the species found in each biozone is given in an attempt to reduce the effects of reworking, dissolution and ecological influences on the assemblages. As a result the definitions of the zones will be more lengthy and seemingly less precise. The species chosen as biohorizon markers were selected on the basis of the following:-

1. Distinct first occurrence, established and correlated in as many areas as possible by personal work and from a survey of the literature.
2. Ease of identification in the light microscope.
3. Reasonable abundance in the calcareous nannofossil assemblages.

Finally, the zones are defined with reference to the established chronostratigraphic system for the Jurassic so that the work may be readily communicated to workers unfamiliar with calcareous nannofossils.

10. A BIOSTRATIGRAPHIC CLASSIFICATION SCHEME FOR THE JURASSIC
USING CALCAREOUS NANNOFOSSILS

Annulithus arkelli Zone (BARNARD and HAY 1974)

Limits: From the lowest occurrence of Annulithus arkelli ROOD, HAY & BARNARD 1973 to the lowest occurrence of Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973.

Age: Rhaetian to Lower Hettangian.

Calcareous nannofossil assemblage from this study:

Annulithus arkelli

Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938

Remarks: The lower limit of this zone is tentatively placed at the boundary between the Lower and Upper Rhaetian because of the uncertainty in the identification of specimens from the Lower Rhaetian of the Watchet Section and the possibility of the existence of a pre-Rhaetian record for this species.

Application to the sections examined here:

The zone can only be recognised in the Watchet Section since this is the only section that covers the Rhaetian-Hettangian interval.

Application to other studies:

AMEZIEUX (1972) - The section does not cover the Rhaetian and the marker species is not recorded.

BARNARD and HAY (1974) - The section does not cover the Rhaetian but Annulithus arkelli is one of the first species to be recorded in the Hettangian.

HAMILTON (1977) - This interval is not covered by this study.

PRINS (1969) - The marker species is not recorded.

THIERSTEIN (1976) - The marker species is not recorded.

Crucirhabdus primulus Zone (PRINS 1969)

Limits: From the lowest occurrence of Crucirhabdus primulus to the lowest occurrence of Parhabdolithus liasicus DEFLANDRE 1952.

Age: Hettangian.

Calcareous nannofossil assemblage from this study:

Annulithus arkelli

Schizosphaerella punctulata

Remarks: In the Portuguese sections this interval is not covered and, therefore, the full lower range of Crucirhabdus primulus is not known. The species is not recovered in the Watchet Section, possibly because palaeoenvironmental conditions in the area during the early Jurassic were not suitable for the preservation of full assemblages. Other workers (AMEZIEUX 1972; BARNARD and HAY 1974; PRINS 1969; THIERSTEIN 1976) have recorded several species at this level.

Application to the sections examined here:

The zone cannot be recognised.

Application to other studies:

AMEZIEUX (1972) - This zone is used by the author.

BARNARD and HAY (1974) - This zone can be applied although the lowest occurrence of the marker species is found at the top of the Hettangian rather than at the base of the stage as recorded by most workers.

HAMILTON (1977) - This interval was not examined.

PRINS (1969) - The zone can be applied although PRINS records rare specimens of the marker species in the Rhaetian.

THIERSTEIN (1976) - THIERSTEIN follows PRINS (1969) in describing
the base of Crucirhabdus primulus as Rhaetian.

Parhabdolithus liasicus Zone (STRADNER 1963)

Limits: From the lowest occurrence of Parhabdolithus liasicus to the lowest occurrence of Podorhabdus cylindratus NOEL 1965.

Age: Sinemurian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Hettangian

Schizosphaerella punctulata

b) New species within the Sinemurian

Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975

Calyculus spp.

Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965

Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973

Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968

Parhabdolithus liasicus DEFLANDRE 1952

Parhabdolithus marthae DEFLANDRE 1954

Parhabdolithus sp.

Staurorhabdus quadriarculus (NOEL 1965) NOEL 1973

Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971

c) Notable absences

Annulithus arkelli

Remarks: None of the species first occurrences listed above and shown in the range chart in Text Fig. 36 is regarded as being the true lowest limit of the species because of the break in the sampling of the lowermost Sinemurian. The last appearance of Parhabdolithus marthae at the top of the Sinemurian is regarded as a useful biohorizon.

Application to the sections examined here:

The lower limit of the zone cannot be recognised due to a break in the sampling.

Application to other studies:

AMEZIEUX (1972) - AMEZIEUX proposed a zone of the same name and found the lowest occurrence of Parhabdolithus liasicus at the same level. He did not, however, record Podorhabdus cylindratus which is here used to define the upper limit of the zone. He also recorded the last appearance of Parhabdolithus marthae at the top of the Sinemurian.

BARNARD and HAY (1974) - The zone can be applied to their data but they recorded the lowest occurrence of Podorhabdus cylindratus higher up in the Lower Pliensbachian than is here described.

HAMILTON (1977) - The application of the zone cannot be ascertained since the full lower limit of the marker species is not known. The last appearance of Parhabdolithus marthae is used to define the Parhabdolithus marthae Subzone.

PRINS (1969) - The zone can be applied to PRINS' data.

STRADNER (1963) - This author also proposed a Sinemurian zone with Parhabdolithus liasicus as the marker species but he did not record Podorhabdus cylindratus.

THIERSTEIN (1976) - The zone can only be loosely applied to THIERSTEIN's data since he did not find the base of Podorhabdus cylindratus until the Upper Pliensbachian.

Podorhabdus cylindratus Zone (BARNARD and HAY 1974)

Limits: From the lowest occurrence of Podorhabdus cylindratus to the lowest occurrence of Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968.

Age: Pliensbachian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Sinemurian

Biscutum ellipticum

Calyculus spp.

Crepidolithus cavus

Crepidolithus crassus

Crepidolithus crucifer

Crucirhabdus primulus

Discorhabdus ignotus

Parhabdolithus liasicus

Parhabdolithus sp.

Schizosphaerella punctulata

Staurorhabdus quadriarcullus

Tubirhabdus patulus

Zygodiscus erectus

b) New species within the Pliensbachian

Ellipsagelosphaera sp.

Podorhabdus cylindratus

Striatomarginis veterna (PRINS 1969 ex ROOD, HAY & BARNARD 1973)
WISE & WIND 1976

c) Notable absences

Parhabdolithus marthae

Remarks: The marker species, Podorhabdus cylindratus, is not a very good biostratigraphic indicator because it is usually rare and is

quite difficult to identify in the light microscope.

Application to the sections examined here:

The zone can be recognised in the Brenha Road Section.

Application to other studies:

AMEZIEUX (1972) - Podorhabdus cylindratus was not recorded.

BARNARD and HAY (1974) - The lower limits of the range of Podorhabdus cylindratus do not correlate in terms of ammonite zones although both are found in the Lower Pliensbachian.

HAMILTON (1977) - The Podorhabdus cylindratus Zone as defined by HAMILTON (1977) has a different upper limit to that defined here.

PRINS (1969) - The lowest occurrence of Podorhabdus cylindratus was found at a higher level in the Lower Pliensbachian than is here recorded.

STRADNER (1963) - The marker species was not recorded.

THIERSTEIN (1976) - The zone can be applied although the zonal limits were found at different stratigraphic levels. THIERSTEIN recorded the base of Podorhabdus cylindratus in the Upper Pliensbachian and the base of Ellipsagelosphaera britannica (as Watznaueria communis REINHARDT 1964) in the Lower Bajocian.

Ellipsagelosphaera britannica Zone (This work)

Limits: From the lowest occurrence of Ellipsagelosphaera britannica to the lowest occurrence of Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975.

Age: Toarcian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Pliensbachian

Biscutum ellipticum

Calyculus spp.

Crepidolithus cavus

Crepidolithus crassus

Discorhabdus ignotus

Ellipsagelosphaera sp.

Parhabdolithus sp.

Podorhabdus cylindratus

Schizosphaerella punctulata

Staurorhabdus quadriarcullus

Striatomarginis veterna

Tubirhabdus patulus

Zygodiscus erectus

b) New species within the Toarcian

Carinolithus superbus (DEFLANDRE 1954) PRINS 1969

Diazomatolithus lehmani NOEL 1965

Discorhabdus patulus (DEFLANDRE 1954) NOEL 1965

Discorhabdus tubus NOEL 1965

Ellipsagelosphaera britannica

Podorhabdus macrogranulatus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Striatomarginis primitivus ROOD, HAY. & BARNARD 1973

c) Notable absences

Crepidolithus crucifer

Crucirhabdus primulus

Parhabdolithus liasicus

Remarks: Ellipsagelosphaera britannica is selected as the marker species for this zone because of its world wide distribution and despite its long range into the Cretaceous. Here, the whole assemblage, which is characterised by the first occurrences of several less well known species, should be considered.

Application to the sections examined here:

In Peniche the lower limit of this zone is found in the Lower Toarcian (tenuicostatum Zone) whilst in the Brenha Road Section it is not recorded until the Upper Toarcian (HAMILTON 1977).

Application to other studies:

AMEZIEUX (1972) - Ellipsagelosphaera britannica is regarded as synonymous with Ellipsagelosphaera frequens NOEL 1965 and Watznaueria communis as used by AMEZIEUX. He did not find the bases of these species until the Middle Bajocian.

BARNARD and HAY (1974) - Watznaueria communis as used by these authors is again considered to be a synonym of Ellipsagelosphaera britannica. BARNARD and HAY did not record the species until the Lower Bajocian.

HAMILTON (1977) - The zone can be applied although the base of Ellipsagelosphaera britannica was found at a higher level in the Toarcian.

PRINS (1969) - The marker species was not found by PRINS and his sections do not cover the Toarcian very extensively.

STRADNER (1963) - The zone cannot really be applied due to the restricted assemblages given by STRADNER.

THIERSTEIN (1976) - Watznaueria communis as used by THIERSTEIN is considered a synonym of Ellipsagelosphaera britannica. THIERSTEIN did not record the species until the Lower Bajocian so that the zone as defined here has a limited application.

Ellipsagelosphaera keptalrempti Zone (This work)

Limits: From the lowest occurrence of Ellipsagelosphaera keptalrempti
to the lowest occurrence of Stephanolithion speciosum
DEFLANDRE 1954.

Age: Bajocian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Toarcian

Biscutum ellipticum

Carinolithus superbus

Crepidolithus crassus

Diazomatolithus lehmani

Discorhabdus ignotus

Discorhabdus patulus

Discorhabdus tubus

Ellipsagelosphaera britannica

Podorhabdus cylindratus

Podorhabdus macrogranulatus

Schizosphaerella punctulata

Staurorhabdus quadriarculus

Striatomarginis primitivus

Striatomarginis veterana

Tubirhabdus patulus

Zygodiscus erectus

b) New species within the Bajocian

Bennocyclus decussatus GRÜN, PRINS & ZWIELI 1974

Cretarhabdus sp. 1

Cretarhabdus sp. 2

Cyclagelosphaera margereli NOEL 1965

Discorhabdus sp.

Ellipsagelosphaera keftalrempti

Hexapodorhabdus cuvillieri NOEL 1965

Octopodorhabdus decussatus (MANIVIT 1959) ROOD, HAY & BARNARD 1971

Staurolithites crux (DEFLANDRE 1954) CARATINI 1963

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968

Zygodiscus noeli (ROOD, HAY & BARNARD 1971) n. comb.

c) Notable absences

Calyculus spp.

Crepidolithus cavus

Parhabdolithus sp.

Remarks: This zone has been proposed mainly because of the need for a biostratigraphic event in the interval. The zone marker, Ellipsagelosphaera keftalrempti, is a long ranging species which has only recently been recognised as a separate species distinct from Ellipsagelosphaera britannica. It is not recorded as a separate species in any other Jurassic calcareous nannofossil biostratigraphies, so that comparison with other work is not satisfactory. However, correlation is possible if the whole assemblage is considered.

Application to the sections examined here:

The zone is recognised in the Brenha Road Section.

Application to other studies:

AMEZIEUX (1972) - AMEZIEUX defined a Bajocian Ellipsagelosphaera Subzone using his Watznaueria communis and Ellipsagelosphaera frequens. He did not record the influx of new species which have been identified from the Bajocian in this study.

BARNARD and HAY (1974) - Some correlation can be made in terms of the new species recorded in the Bajocian (Hexapodorhabdus cuvillieri and Octopodorhabdus decussatus). The Bajocian was not very thoroughly examined by BARNARD and HAY due to the lack of suitable sections of this age in southern England.

MOSHKOVITZ and EHRLICH (1976) - In their discussion of the Hexalithus magharensis Zone, the authors stated that "Ellipsagelosphaera communis (REINHARDT 1964) PERCH-NIELSEN 1968 lacks the typical transverse bridge and the form is smaller than those present in the Upper Jurassic." This description suggests that the species might be Ellipsagelosphaera keftalrempti, although none of the illustrations confirm this possibility.

STRADNER (1963) - The zone cannot be applied because of the restricted assemblage described by STRADNER.

THIERSTEIN (1976) - The zone cannot be applied to THIERSTEIN's data.

Stephanolithion speciosum Zone (AMEZIEUX 1972)

Limits: From the lowest occurrence of Stephanolithion speciosum
DEFLANDRE 1954 to the lowest occurrence of Stephanolithion
bigoti DEFLANDRE 1939.

Age: Bathonian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Bajocian

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Discorhabdus ignotus

Discorhabdus patulus

Discorhabdus sp.

Discorhabdus tubus

Ellipsagelosphaera britannica

Ellipsogelosphaera keftalrempti

Hexapodorhabdus cuvillieri

Octopodorhabdus decussatus

Podorhabdus cylindratus

Podorhabdus macrogranulatus

Schizosphaerella punctulata

Staurolithites crux

Staurorhabdus quadriarcullus

Striatomarginis primitivus

Tubirhabdus patulus

Watznaueria barnesae

Zygodiscus erectus

Zygodiscus noeli

b) New species within the Bathonian

Diazomatolithus sp.

Discorhabdus biperforatus ROOD, HAY & BARNARD 1973

Discorhabdus jungi NOEL 1965

Ellipsagelosphaera cruci centralis MEDD 1971

Stephanolithion speciosum

Stephanolithion speciosum var. octum ROOD & BARNARD 1972

Tetralithus gothicus DEFLANDRE 1959

Watznaueria biporta BUKRY 1969

c) Notable absences

Carinolithus superbus

Crepidolithus crassus

Cretarhabdus sp. 1

Cretarhabdus sp. 2

Striatomarginis veterna

Remarks: The biohorizons marking the limits of this zone are very distinct because the marker species are easy to recognise in the light microscope.

Application to the sections examined here:

The lower limit of this zone is found near the bottom of the Bathonian in the Brenha Road Section and at the base of the Bathonian in the Cap Mondego Section 1. The Cap Mondego Section 2 lies within the Stephanolithion speciosum Zone.

Application to other studies:

AMEZIEUX (1972) - This zone was used by AMEZIEUX.

BARNARD and HAY (1974) - The earlier appearance of Stephanolithion speciosum in the Lower Bajocian of southern England renders the application of the zone, as defined here, impossible.

MOSHKOVITZ and EHRLICH (1976) - This zone was used by these authors.

STRADNER (1963) - Stephanolithion speciosum was not recorded by STRADNER.

THIERSTEIN (1976) - This zone can be applied to THIERSTEIN's data.

Stephanolithion bigoti Zone (STRADNER 1963)

Limits: From the lowest occurrence of Stephanolithion bigoti to the lowest occurrence of Polypodorhabdus madingleyensis BLACK 1968.

Age: Lower to Middle Callovian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Bathonian

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Diazomatolithus sp.

Discorhabdus biperforatus

Discorhabdus ignotus

Discorhabdus jungi

Discorhabdus patulus

Discorhabdus sp.

Discorhabdus tubus

Ellipsagelosphaera britannica

Ellipsagelosphaera crucicentralis

Ellipsagelosphaera keftalrempti

Hexapodorhabdus cuvillieri

Octopodorhabdus decussatus

Podorhabdus cylindratus

Schizosphaerella punctulata

Staurolithites crux

Staurorhabdus quadriarcullus

Stephanolithion hexum

Stephanolithion speciosum

Stephanolithion speciosum var. octum

Tetralithus gothicus

Tubirhabdus patulus

Watznaueria barnesae

Watznaueria biporta

Zygodiscus erectus

Zygodiscus noeli

b) New species within the Lower and Middle Callovian

Ethmorhabdus gallicus NOEL 1965

Zygodiscus elegans GARTNER 1968 .

c) Notable absences

Podorhabdus macrogranulatus

Striatomarginis primitivus

Remarks: The assignment of the lower limit of this zone to the base of the Callovian is made from the Deep Sea Drilling Project record at sites 100 and 105. This accords with the data of other workers (AMEZIEUX 1972; MOSHKOVITZ and EHRLICH 1976; ROOD and BARNARD 1972; STRADNER 1963; THIERSTEIN 1976) although in Portugal the species is not found until the Lusitanian.

Application to the sections examined here:

The zone can be recognised in the western North Atlantic Sections and in the Torres Vedras Section from Portugal. The Skye Section lies stratigraphically above the Stephanolithion bigoti Zone although the marker species is found throughout the section. The species is not found in the Cap Mondego Section 1 which is thought to be of Middle Bajocian to Lusitanian age. It is also absent in the Alcanede-Carvalhos Road Section, but this is thought to reflect the brackish water conditions that prevailed during the deposition of the section.

Application to other studies:

- AMEZIEUX (1972) - Although AMEZIEUX recorded the same stratigraphic range for Stephanolithion bigoti (Callovian-Oxfordian), he did not find the marker species for the upper limit of the zone, Polypodorhabdus madingleyensis.
- BARNARD and HAY (1974) - Stephanolithion bigoti was first recorded by these authors at the top of the Lower Callovian and Polypodorhabdus escaigi NOEL 1965 (a synonym of Polypodorhabdus madingleyensis) was found near the base of the Middle Callovian. Therefore, if the zone was applied to this data it would not be so stratigraphically extensive as is here envisaged.
- MOSHKOVITZ and EHRLICH (1976) - A Stephanolithion bigoti Zone was proposed by these authors which has the same lower limit as is here described. Polypodorhabdus madingleyensis was not found and the upper limit of their zone was simply marked by the upper limit of Stephanolithion bigoti at the top of the Oxfordian.
- STRADNER (1963) - STRADNER proposed a Stephanolithion bigoti Association which was again based only on the presence of Stephanolithion bigoti and covers the Callovian to Oxfordian interval. Polypodorhabdus madingleyensis was not recorded.
- THIERSTEIN (1976) - The zone can be applied to THIERSTEIN's data although he did not find Polypodorhabdus

escaigi. (a synonym of Polypodrhodus
madingleyensis) until the base of the
Oxfordian whilst it is here first recorded
in the Upper Callovian.

Polypodorhabdus madingleyensis Zone (This work)

Limits: From the lowest occurrence of Polypodorhabdus madingleyensis
to the lowest occurrence of Parhabdolithus embergeri (NOEL 1958)
STRADNER 1963.

Age: Upper Callovian to Middle Kimmeridgian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Lower and Middle Callovian

i. Those which are found throughout the zone

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Discorhabdus biperforatus

Discorhabdus ignotus

Ellipsagelosphaera britannica

Ellipsagelosphaera keftalreempti

Podorhabdus cylindratus

Staurorhabdus quadriarcullus

Tetralithus gothicus

Watznaueria barnesae

Watznaueria biporta

Zygodiscus elegans

Zygodiscus erectus

Zygodiscus noeli

ii. Those which disappear within the zone

Diazomatolithus sp.

Discorhabdus jungi

Discorhabdus patulus

Discorhabdus sp.

Discorhabdus tubus

Ellipsagelosphaera crucicentralis

Ethmorhabdus gallicus

Hexapodorhabdus cuvillieri

Octopodorhabdus decussatus

Schizosphaerella punctulata

Staurolithites crux

Stephanolithion bigoti

Stephanolithion hexum

Stephanolithion speciosum

Stephanolithion speciosum var. octum

Tubirhabdus patulus

b) New species within the Upper Callovian to Middle Kimmeridgian

Actinozygus geometricus (GORKA 1957) ROOD, HAY & BARNARD 1971

Polypodorhabdus madingleyensis

Stradnerlithus asymmetricus (ROOD, HAY & BARNARD 1971) NOEL 1973

c) Notable absences

None

d) Possible contaminants from younger sediment

Hemipodorhabdus gorkae (REINHARDT 1969) GRÜN & ALLEMANN 1975

Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971

Perrisocyclus sp.

Retecapsa angustiforata BLACK 1971

Retecapsa schizobrachiata (GARTNER 1968) GRÜN & ALLEMANN 1975

Tubodiscus verenae THIERSTEIN 1973

Remarks: This is a long ranging zone in which many minor stratigraphic events occur. These are mainly last appearances of species; their use in biostratigraphy is generally not encouraged because

these are often found to be inconsistent over a wide geographic area and are susceptible to reworking. However, the last appearance of Stephanolithion bigoti has been used as a biohorizon to indicate the top of the Oxfordian by many workers (BARNARD and HAY 1974; MOSHKOVITZ and EHRLICH 1976; STRADNER 1963; THIERSTEIN 1976).

Application to the sections examined here:

Part of this zone is recognised in the Staffin Section on the Isle of Skye. The zone is also recognised in the Torres Vedras Section in Portugal and at Deep Sea Drilling Project Site 105.

Application to other studies:

AMEZIEUX (1972) - The marker species for this zone were not recorded and the sections did not cover the whole of the Kimmeridgian.

BARNARD and HAY (1974) - The zone can be applied to BARNARD and HAY's data although they did not record the base of Parhabdolithus embergeri until the Upper Kimmeridgian.

MOSHKOVITZ and EHRLICH (1976) - This stratigraphic interval was not wholly covered and the marker species were not recorded.

STRADNER (1963) - The limited assemblages recorded for the Oxfordian and Kimmeridgian do not enable application of this zone to STRADNER's data.

THIERSTEIN (1976) - Parhabdolithus embergeri was not recorded.

Parhabdolithus embergeri Zone (BARNARD and HAY 1974)

Limits: From the lowest occurrence of Parhabdolithus embergeri to the lowest occurrence of Conusphaera mexicana TREJO 1969.

Age: Middle and Upper Kimmeridgian.

Calcareous nannofossil assemblage from this study:

a) Species present from the Upper Callovian to Lower Kimmeridgian

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Discorhabdus biperforatus

Discorhabdus ignotus

Ellipsagelosphaera britannica

Ellipsagelosphaera keftalrempi

Podorhabdus cylindratus

Polypodorhabdus madingleyensis

Staurorhabdus quadriarcullus

Tetralithus gothicus

Watznaueria barnesae

Watznaueria biporta

Zygodiscus elegans

Zygodiscus erectus

Zygodiscus noeli

b) New species within the Middle and Upper Kimmeridgian

Parhabdolithus embergeri

c) Notable absences

Discorhabdus patulus

Ethmorhabdus gallicus

Hexapodorhabdus cuvillieri

Octopodorhabdus decussatus

Schizosphaerella punctulata

Stephanolithion bigoti

Tubirhabdus patulus

d) Possible contaminants from younger sediment

Manivitella pemmatoidea

Perrisocyclus sp.

Tubodiscus verenae

Remarks: The assignment of a Middle Kimmeridgian age to the lower limit of this zone is tentative because of the lack of sufficient detail regarding the age of the uppermost Jurassic sections.

Application to the sections examined here:

The zone can be recognised at Deep Sea Drilling Project Sites 99A and 105.

Application to other studies:

BARNARD and HAY (1974) - The zone can be applied in part only since their sections do not cover the Tithonian interval.

STRADNER (1963) - This zone cannot be applied since STRADNER did not find Parhabdolithus embergeri until the Purbeckian.

THIERSTEIN (1976) - The zone cannot be applied due to the absence in THIERSTEIN's range chart of Parhabdolithus embergeri.

WORSLEY (1971) - WORSLEY did not record Conusphaera mexicana but his range for Parhabdolithus embergeri accords with this zone.

Conusphaera mexicana Zone (THIERSTEIN 1975)

Limits: From the lowest occurrence of Conusphaera mexicana to the lowest occurrence of Nannoconus steinmanni KAMPTNER 1931.

Age: Tithonian

Calcareous nannofossil assemblage from this study:

a) Species present from the Upper Kimmeridgian

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Discorhabdus ignotus

Ellipsagelosphaera britannica

Ellipsagelosphaera keftalrempti

Parhabdolithus embergeri

Podorhabdus cylindratus

Polypodorhabdus madingleyensis

Tetralithus gothicus

Watznaueria barnesae

Watznaueria biporta

Zygodiscus elegans

Zygodiscus erectus

Zygodiscus noeli

b) New species within the Tithonian

Conusphaera mexicana

c) Notable absences

None

d) Possible contaminants from younger sediment

Manivitella pemmatoidea

Perrisocyclus sp.

Tubodiscus verenae

Remarks: In this study the Tithonian stage was not thoroughly investigated but it was found that THIERSTEIN's (1975) Conusphaera mexicana Zone could be applied to the available data. Conusphaera mexicana has not been found in Great Britain (MEDD, personal communication) but THIERSTEIN (1975) did record the species in two sections from France.

Application to the sections examined here:

This zone is recognised at Deep Sea Drilling Project Site 105. The assemblages recorded at Site 99A, where the base of Parhabdolithus embergeri and the base of Conusphaera mexicana are found at the same level, are not regarded as reliable on the grounds of shipboard reports of contamination and the presence of definite Tertiary contaminants (Discoasters) in the Jurassic part of that core.

Application to other studies:

STRADNER (1963) - The zone cannot be applied since STRADNER did not recognise Conusphaera mexicana.

THIERSTEIN (1975) - This publication contains the original definition of the zone.

THIERSTEIN (1976) - His zone can be applied to the data in his range chart (THIERSTEIN, 1976, Fig. 7).

WORSLEY (1971) - The zone cannot be used since Conusphaera mexicana was not recorded.

Nannoconus steinmanni Zone (BRONNIMANN 1955)

Limits: From the lowest occurrence of Nannoconus steinmanni to the lowest occurrence of Cretarhabdus crenulatus BRAMLETTE & MARTINI 1964 emend. THIERSTEIN 1971.

Age: Lower Cretaceous (Berriasian).

Calcareous nannofossil assemblage from this study:

a) Species present from the Tithonian

Biscutum ellipticum

Cyclagelosphaera margereli

Diazomatolithus lehmani

Discorhabdus ignotus

Ellipsagelosphaera britannica

Ellipsagelosphaera keftalrempti

Manivitella pemmatoidea

Parhabdolithus embergeri

Podorhabdus cylindratus

Tetralithus gothicus

Tubodiscus verenae

Watznaueria barnesae

Watznaueria biporta

Zygodiscus elegans

Zygodiscus erectus

Zygodiscus noeli

b) New species within the Berriasian

Cruciellipsis cuvillieri (MANIVIT 1966) THIERSTEIN 1971

Markalius inversus (DEFLANDRE 1954) BRAMLETTE & MARTINI 1964

Micrantholithus holschulzi (REINHARDT 1966) THIERSTEIN 1971

Nannoconus steinmanni

Nannoconus truitti BRONNIMANN 1955

c) Notable absences

None

Remarks: Although this study was not strictly concerned with the Lower Cretaceous, the presence of some Berriasian sediment in the Deep Sea Drilling Project samples enabled the author to pursue this Jurassic biostratigraphy to a logical conclusion at a point where it can be linked up to the more established Lower Cretaceous schemes. Only the lower part of this zone has been recognised in this study. The assignment of a Berriasian age to this part of the zone is tentative because of the lack of detailed information regarding the age of the uppermost Jurassic sediment.

Application to the sections examined here:

The zone is recognised at Deep Sea Drilling Project Site 105. At Site 99A the base of Nannoconus steinmanni is recorded at the same level as the bases of Parhabdolithus embergeri and Conusphaera mexicana, but as mentioned above, this evidence is considered to be unreliable.

Application to other studies:

BALDI-BEKE (1962) - This author found Nannoconus steinmanni in the Middle Tithonian.

BRONNIMANN (1955) - The zone can be applied to BRONNIMANN's data although in his chart the lower limit of the range of Nannoconus steinmanni was marked in a dotted line suggesting a possible pre-Cretaceous history for the species.

GEEL (1966) - This author also found Nannoconus steinmanni in the Tithonian although he noted that the precise age of his sections was not well known.

- STRADNER (1963) - STRADNER recorded Nannoconus steinmanni in the Upper Tithonian but noted that "Nannoconids are valuable zone-markers in the Lower Cretaceous".
- THIERSTEIN (1975) - The zone can be applied to THIERSTEIN's data. The species regarded by him as Nannoconus colomi (de LAPPARENT 1931) KAMPTNER 1938 is here considered to be a synonym of Nannoconus steinmanni.
- THIERSTEIN (1976) - The zone can be applied to THIERSTEIN's range chart although in this paper he used Cretarhabdus angustiforatus (BLACK 1971) THIERSTEIN 1976 as the marker species for the upper limit of the zone. Nannoconus colomi is again regarded as a synonym of Nannoconus steinmanni.
- WORSLEY (1971) - WORSLEY recorded Nannoconus steinmanni in the Tithonian.

11. A REVIEW OF THE PHENOMENA WHICH INFLUENCE THE CALCAREOUS NANNOFOSSIL ASSEMBLAGE

11.1. Introduction

The biostratigraphic and correlatory use of Cretaceous and Tertiary calcareous nannofossils has been fairly well demonstrated. Attempts are now being made to refine the biostratigraphic schemes for these two systems by evaluating the influences of preservation, evolution and environmental factors on the composition of calcareous nannofossil assemblages and the subsequent interpretation of the fossil record. Although Jurassic biostratigraphy using calcareous nannofossils is not yet as well established, a knowledge of these phenomena is equally valuable to the Jurassic worker.

11.2. Preservation

While no work regarding preservation has been carried out on Jurassic assemblages, observations made by other workers on younger assemblages and data described from experimental work on younger sediments provide a background of theoretical knowledge. This is directly applicable where species can be correlated and assists in the interpretation of fossil assemblages even where direct correlation is not possible.

The preservation of calcareous nannofossils is affected by two related but opposed chemical processes:

1. Dissolution of calcite elements
2. Secondary overgrowth of calcite.

1. Dissolution

Solution effects are twofold:

- a. Certain crystal elements in an individual specimen are more susceptible to solution than others. BAIN (1940) showed that different crystal faces of calcite have varying solubilities. He found that the faces orientated perpendicular to the c-axis are most resistant to solution while those that are parallel to the c-axis are least resistant. BUKRY (1971a) related the orientation of the optic axis of the elements of coccoliths to their susceptibility to dissolution and ultimately to the solution resistance of the species.
- b. Solution is also species preferential. Smaller and more delicate coccoliths with non-imbricate rims and great expanses of exposed surfaces are more susceptible to solution than large forms with strongly imbricate elements which are arranged so that the surface area of the individual microcrystals is minimal. BUKRY (1973) noted that discoasters are less susceptible to solution than the placolith type of calcareous nannofossil. He attributed the resistance to solution of discoasters to their large size and crystal orientation.

HILL (1975) summarised susceptibility to dissolution as being determined by "the size of the individual (the volume of calcite present) and the microstructure of the calcite crystals (the surface area exposed)".

Dissolution can, therefore alter the appearance of an individual or the composition of a whole nannofossil assemblage or both. Dissolution effects can be recognised by the following:

1. Serrate margins of coccoliths
2. Central cross structures and delicate meshes absent or fragmented
3. Enlarged central pore areas.

The work of BUKRY (1971b, 1973), ROTH (1973), WISE (1973), THIERSTEIN (1974, 1976) and ROTH, WISE and THIERSTEIN (1975) suggests that there is a dissolution ranking order for Cenozoic and Mesozoic calcareous nannofossil genera. THIERSTEIN (1976) listed the species which he found to be either solution resistant or susceptible to dissolution from a survey of 37 strongly dissolved samples of Cretaceous sediment. The lists below give only those of THIERSTEIN's species which were recorded in this study.

Solution resistant species:-

Cyclogelosphaera margereli NOEL 1965

Cruciellipsis cuvillieri (MANIVIT 1966) THIERSTEIN 1971

Diazomatolithus lehmani NOEL 1965

Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971

Nannoconus spp.

Parhabdolithus embergeri (NOEL 1958) STRADNER 1963

Tubodiscus verenae THIERSTEIN 1973 emend. GRÜN & ALLEMANN 1975

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968

Watznaueria britannica (STRADNER 1963) REINHARDT 1964

Zygodiscus elegans GARTNER 1968

THIERSTEIN noted that "their absence in any one assemblage of the same age can not be explained by dissolution only".

His list of species that are susceptible to solution includes only one of the species that was found in this study, Corollithion ellipticum BUKRY 1969 (a synonym of Actinozygus geometricus (GORKA 1957) ROOD, HAY & BARNARD 1971). Again, THIERSTEIN noted that the "absence of other species of the same age in an assemblage containing these species can not be due to solution". From the results of this work and, more particularly, from the results of the experiment described

earlier in the chapter on method (Chapter 2) the following species might be added to this list:-

Ethmorhabdus gallicus NOEL 1965

Staurorhabdus quadriarculus (NOEL 1965) NOEL 1973

Stradnerlithus asymmetricus (ROOD, HAY & BARNARD 1971) NOEL 1973.

2. Secondary calcite overgrowth

Overgrowth is similarly selective. Certain parts of specimens or certain species may be more susceptible to overgrowth than others. For example, overgrowth can produce an irregular outline in coccoliths or it can obliterate central structures. ROTH and THIERSTEIN (1972) found that overgrowth affects discoasters more than coccoliths. They noted that the general outline of coccoliths is usually preserved so that they "can still be identified when discoasters are so strongly overgrown that the original species can no longer be recognised". This phenomenon was also noted by BUKRY (1973).

Secondary calcite overgrowth is largely independant of age. For example, HILL (1975) noted that "some early Cretaceous assemblages are as well preserved as their modern counterparts". Similarly, in this study the author has not found that the age of the assemblage influences its preservation. This is amply demonstrated by comparing some of the very well preserved specimens shown in the Plates in this volume with some of the illustrations of more recent assemblages in the literature.

The degree of overgrowth is, however, thought to depend on lithology and in particular on the calcium carbonate and clay content of the sediment. Permeable sediments such as calcareous oozes, chalks and limestones which have a high calcium carbonate content and a low

clay content produce calcareous nannofossil assemblages which show more overgrowth than those from marls. The clay content is therefore thought to influence the preservation of calcareous nannofossils. This suggests that the free flow of water through the sediment (permeability of the sediment) rather than the ability of the sediment to absorb water (porosity) is important since clays are porous but not permeable.

The depth of burial of assemblages is also thought to influence the state of preservation of calcareous nannofossils. ROTH and THIERSTEIN (1972) found that calcareous nannofossils "recovered from calcareous ooze at a depth of less than 150 m subbottom show hardly any signs of overgrowth but most assemblages below 150 m - 200 m show overgrowths".

In this study the author noted that assemblages obtained from the Deep Sea Drilling Project cores were generally better preserved than those in sediments collected from land based sites. Since the Deep Sea Drilling Project samples were mainly in soft limestones and the Portuguese samples, for example, were mostly marls the results are in direct contrast to the theory described regarding the clay content of the sediment. In this case the poor preservation of most of the Portuguese assemblages probably resulted from the effects of subaerial erosion on the sediment.

Secondary calcite overgrowth was noted on the larger, more robust forms such as Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965. In some assemblages the specimens of Crepidolithus crassus could only be recognised from their outline and size, whilst in others, clean well preserved specimens were found. Also, the experiment which is described in Chapter 2 clearly demonstrated the effects of secondary calcite overgrowth on specimens of Stephanolithion bigoti DEFLANDRE 1939.

The series of photographs of this species (Pl. 8, Figl. 1-4) illustrate the progressive change which occurred over the twelve week experimental period. The protruding spines that are so characteristic of this species gradually grew thicker so that the final specimen (Pl. 8, Fig. 4) bears little resemblance to the first, unaltered form (Pl. 8, Fig. 1).

In some samples dissolution and secondary calcite overgrowth are found in the same assemblage. ROTH and THIERSTEIN (1972) described samples in which "the coccoliths show serrate margins and other signs of etching, whereas the arms of the discoasters are overgrown with secondary calcite". They suggested that the dissolution occurred while the assemblage was exposed to the bottom waters and that the secondary calcite overgrowth was precipitated in the sediment at a later time.

BUKRY (1973) developed a qualitative preservation key system which enables workers to assess the degree of overgrowth and solution which has affected their assemblages in a form which may be readily used for comparative purposes. The system is also most useful for providing brief statements about preservation. However, the system has not been applied in this study although future studies might consider using such a scheme.

SCHLANGER et al (1973) described the diagenetic processes that give rise to dissolution and overgrowth. The process begins with the death of the organism. The skeletal material sinks through the water column as discrete particles or in faecal material. Selective dissolution of the calcareous nannofossils occurs as the skeletal matter sinks below the lysocline towards the sea floor. An abrupt increase in calcium carbonate dissolution at a certain depth in the deep oceans marks the calcium carbonate compensation depth (C.C.D.) below which calcareous matter is dissolved. This is the major facies boundary in the deep seas because it separates calcareous oozes from carbonate-poor sediments.

BERGER (1971) showed that calcium carbonate compensation results in a foraminifera lysocline below which foraminifera are severely affected by solution. He later demonstrated that the foraminifera lysocline is the coccolith lysocline as well. MCINTYRE and MCINTYRE (1971) stated that coccoliths show the best resistance to dissolution with depth of the carbonate secreting forms, especially foraminifera. Results from the Deep Sea Drilling Project have confirmed that calcareous nannofossils are more solution resistant than planktonic foraminifera (BUKRY et al 1971). Calcareous nannofossils therefore have a lower compensation depth than foraminifera and consequently present a more complete biostratigraphic record in deep sea sections. It is thought that the resistance to solution shown by calcareous nannofossils is due in part to a proteinaceous membrane that covers the calcite elements (HILL 1975).

The selective preservation of fossil assemblages is intensified after burial. Continued dissolution causes a reduction in the volume of the sediment. The weaker and more delicate forms are broken and crushed exposing a greater surface area and thus encouraging dissolution. The destruction of skeletal elements causes a build up of calcium carbonate in the sediment. This calcium carbonate can be precipitated as secondary overgrowth on the more resistant species or it may precipitate as small, irregular grains, known as "Micrite" or it may form an interstitial cement.

While much of the information on preservation in calcareous nannofossils has been obtained during the normal examination of sediment from many different areas, the topic has been further investigated by experimental work in laboratories.

ADELSECK, GEEHAN and ROTH (1973) subjected some samples to

extremely high pressure and temperature in order to produce in one month effects similar to those produced in millions of years of natural diagenetic conditions. Their results confirmed the findings described above:

1. Smaller and more delicate coccoliths were more easily dissolved than larger forms with overlapping elements.
2. Some larger forms showed signs of etching but generally demonstrated the formation of secondary overgrowth.
3. Smaller coccoliths underwent dissolution and this provided calcium carbonate for precipitation onto larger elements. The secondary overgrowths tended to bond the elements together and further prevent disaggregation.

HILL (1975) bubbled carbon dioxide through a suspension of calcareous nannofossils for a period of five hours to study the effects of dissolution. The change in the calcareous nannofossil assemblage was studied at hourly intervals. HILL noted that "the most striking overall change is the dramatic increase in the percentage of micrite to coccoliths". His untreated sample contained approximately 50% micrite while the five hour sample contained over 99% micrite. But, in spite of the amount of calcium carbonate in solution, secondary calcite overgrowth on the calcareous nannofossils was not observed. After the conclusion of the experiment the samples were retained for several months to see if secondary overgrowth would appear as expected. However, no overgrowth was observed, which contrasts with the observations made in this study and with the descriptions of other authors.

SCHLANGER et al (1973) emphasised the importance of preservation in the study of calcareous nannofossils when they noted that "the selectivity of these processes in destroying certain species while

leaving other species relatively unaffected, introduces an important bias which influences the interpretation of microfossil assemblages".

THIERSTEIN (1976) described how the effects of preservation can result in morphologically related species having the same stratigraphic interval with their relative abundance depending only on the degree of diagenesis that has affected the samples.

In this study the form known as Calolithus martelae NOEL 1965 is regarded as a product of the dissolution of Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 or perhaps one of the species of Ellipsagelosphaera. It has the same stratigraphic range as these species and is not recognised as a distinct form.

THIERSTEIN (1976) noted that "additional studies of the morphological effects of diagenesis on a number of Mesozoic (calcareous nannofossil) taxa appear to be necessary to delineate clear taxonomic concepts which will improve their usefulness in biostratigraphic and palaeoecologic interpretations".

Clearly, preservation is an important phenomenon in determining the composition of calcareous nannofossil assemblages. With our limited knowledge of the Jurassic flora it is hard to assess the degree to which our interpretation of the fossil record is affected by preservation. This will become more possible as further research is carried out. However, in the meantime the theoretical knowledge should be remembered.

11.3. Evolution

While the author appreciates that it is the living organism (the coccolithophorid, for example) and not its calcareous, skeletal elements (the coccoliths) that evolves, it is convenient here to apply the term "evolution" to the structural changes that are seen in calcareous nannofossils over a period of time.

As yet very little work has been carried out on evolutionary change in calcareous nannofossils and no phylogenetic lineages have been identified.

PRINS (1969), in his study of Lower and Middle Lias coccoliths, suggested that the similarity of coccolithophorid algae to advanced forms of chrysomonad algae (plate scales at the surface of the cell, the shape and number of flagellae, the presence of a haptonema and the colour, shape and number of chromatophores) points to a close relationship between these phytoflagellates. He proposed that at some stage the scale bearing chrysomonads evolved into coccolithophorids; the major difference between the two is that the latter have calcite elements on their plate scales. PRINS continued this evolutionary theme by suggesting that seven lines of structural development stemmed from Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 which was at that time the oldest known coccolith. He described how the rim and the central structure of this species change to produce Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973 Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973 Paleopontosphaera veterna PRINS 1969 ex ROOD, HAY & BARNARD 1973 Parhabdolithus liasicus DEFLANDRE 1952 Parhabdolithus marthae DEFLANDRE 1954 Podorhabdus cylindratus NOEL 1965 Podorhabdus macrogranulatus PRINS 1969 ex ROOD, HAY & BARNARD 1973 Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973.

Since PRINS' work, data has been published which renders unlikely the possible evolution of most of the Lower Jurassic species from his single, possibly Rhaetian species. BARNARD and HAY (1974)

recorded five species in the Lower Hettangian but did not find Crucirhabdus primulus until near the top of the Hettangian. Also, HAMILTON (1977) recorded twelve species in the Lower Sinemurian, that is twice as many species as are shown at the same level in PRINS' range chart (PRINS 1969, Table 1), and suggested that such a diversification from the single, simple Rhaetian species is unlikely to have occurred in this short stratigraphic interval. The results of the investigation of Rhaetian and Hettangian samples from Watchet in North Somerset, presented in an earlier chapter of this study, further suggest that PRINS' scheme is inadequate. In the Watchet Section Crucirhabdus primulus was not recorded at all. Instead specimens of Annulithus arkelli ROOD, HAY & BARNARD 1974 and Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938 were found. It is clear, therefore, that Crucirhabdus primulus is not the only pre-Jurassic representative of the calcareous nannofossils.

The presence of Annulithus arkelli and Schizosphaerella punctulata in the Rhaetian part of the Watchet Section, which is part of a transgressive sequence, suggests that a pre-Rhaetian history for calcareous nannofossils is likely to be found in a different geographical area and a different geological setting.

The oceans of Triassic and Rhaetian times were fairly restricted in their geographic extent. The Tethys Sea, however, occupied quite a large area. It lay in the low latitudes and it was relatively homogeneous and ecologically stable. STEHLI, DOUGLAS and NEWELL (1969) showed that the progressive increase in biotic diversity from high to low latitudes is characteristic not only of the present day but also of the past back to the Permian at least. Some authors (GORDON 1974; REID 1967; STEVENS 1963) have discussed the likelihood that the Tethys Sea

was an important centre for the evolution and dispersal of new marine species during Mesozoic time. This speculation must result partly through a lack of alternative areas due to the restricted extent of the oceans of the time. Other workers prefer to emphasise that during the Mesozoic there was a peculiar fauna characteristic of the Tethys Sea. SYLVESTER-BRADLEY (1967) warned against the dangers of interpreting the record of an organism first discovered in the Mediterranean and subsequently elsewhere in the Northern Hemisphere as a "Tethyan invader of the Boreal Province" and vice versa. However, it is clear that the Tethys Sea did provide a favourable environment.

With this in mind, the author was most fortunate in having the opportunity to examine four samples from the Rhaetian and three from the Triassic of Italy which were collected by Dr. A.R. Lord. The work is not formally included in this study but the results are of interest in this discussion of the early calcareous nannofossil record.

The four Rhaetian samples proved to be barren. However, the three Triassic samples, which came from Mt. Morro, to the east of Rome and near St. Polo and Tivoli, contained some calcareous nannofossils. At Mt. Morro there are Upper Triassic dolomites in slickensided blocks. The three samples were taken from some black clay which was found in association with the dolomite and which was seen to be locally in stratigraphic sequence with the latter. Despite the tectonic disturbance the author has every reason to believe that the black clay is also of Triassic age. The following species were found:-

1. Annulithus arkelli ROOD, HAY & BARNARD 1974.

Positive identification of this small and rare form was made in all the samples.

2. Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968.

Well preserved specimens were quite common.

3. Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938.

No complete specimens were recorded. Identification of fragments was tentative.

4. Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973.

Only one specimen was found.

Following this it is quite possible that the specimens described as calcareous nannofossils from the Permian of Turkey (PIRINI RADRIZZANI 1971), which closely resemble the simple form, Annulithus arkelli, are the earliest known forms of this group. The hiatus in the record that has previously existed between the fairly well documented Lower Jurassic calcareous nannofossils and these Permian forms, together with the great difference that exists in their construction has prevented positive recognition of the early forms as members of the group. However, the presence of these well known forms in sediment of Triassic age and the similarity of Annulithus arkelli to the Permian specimens permits (tentative) recognition of these early specimens.

Further studies on evolution in calcareous nannofossils have been made by ROOD and BARNARD (1972) and THIERSTEIN (1976).

In a discussion of the "Stratigraphic History of Stephanolithion" ROOD and BARNARD (1972) described the possible evolution in the Upper Bathonian of Stephanolithion speciosum var. octum ROOD & BARNARD 1972 from the Lower and Middle Bathonian form, Stephanolithion speciosum DEFLANDRE 1954. This development involves a considerable change in the length of the protruding spines and the authors did not record any transitional forms. This evolutionary link is further rendered unlikely by the contemporaneous first occurrence of the two species at the base of the Bathonian in the Portuguese sections at Brenha and Cap Mondego.

THIERSTEIN (1976) also discussed a possible evolutionary link between two species that have been recorded in this study. He suggested that during the Tithonian Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971 increased in size and evolved into Parhabdolithus embergeri (NOEL 1958) STRADNER 1963. However, in this study the two species were found together in the Tithonian. Also, the appearance of Parhabdolithus embergeri in the Middle Kimmeridgian was quite abrupt. The suggested phylogenetic lineage is, therefore, unlikely.

THIERSTEIN (1976) noted that "most investigators of Mesozoic nannofossils state that morphologically distinct taxa seem to appear abruptly". He continued by saying that "this may be true for certain species but the reason for our ignorance of evolutionary lineages more probably lies in coarse stratigraphic spacing of samples and the use of the light microscope for routine investigation".

From this study the author concludes that at this stage no phylogenetic lineages can be identified in Jurassic calcareous nannofossils but rather that morphologically distinct species seem to appear abruptly. However, it is acknowledged that detailed sampling and extensive electron microscopic examination might reveal evolutionary trends in calcareous nannofossils.

11.4. Palaeoenvironment

To gain an understanding of the effects of palaeoenvironment on fossil assemblages it is clearly most convenient to study Recent calcareous nannoplankton.

Coccoliths and braarudosphaerids are known in the phytoplankton of modern oceans and of these the former are by far the best known. Coccolithophorid algae are restricted to the euphotic zone, that is the

upper 150 m of the water column and with diatoms and dinoflagellates they comprise the bulk of the marine phytoplankton. They are thought to live mainly by photosynthesis although under certain conditions they may ingest food particles or absorb nutrients from their surroundings. Most of our knowledge about the living organism results from laboratory studies under conditions that are probably far from nature. The minute size of the living organism (approximately 2 - 20 μm) has, until recently, prevented successful ocean sampling. This is now possible with the use of membrane surface filters with a pore size of less than 1 μm . An understanding of the modern biogeographic distribution of coccolithophorids can now be obtained by ocean sampling.

Their restriction to the euphotic zone places coccolithophorids under a more direct climatic control than other groups of planktonic forms that are important in the fossil record. Their distribution appears to be closely related to the temperature of ocean surface waters. Where the species composition for various water masses is known the species can be grouped into floras representative of various climates. The majority of coccolithophorids are warm water species and they reach their acme in low and middle latitudes. Species diversity diminishes towards high latitudes (BYBELL and GARTNER 1972; HASLE 1960; HULBERT 1963; MCINTYRE and BÉ 1967; MCINTYRE, BÉ and ROCHE 1970; OKADO and HONJO 1973).

Other ecological factors which are considered by some authors to be of importance are light and salinity. However, at this stage little is known about the influence of these phenomena in controlling the geographic distribution of species.

After the death of the coccolithophorid the skeletal remains, the coccoliths, sink through the water column towards the sea floor.

When they reach the sea floor they are subjected to ocean floor currents and winnowing. These processes can alter the composition of the original assemblage and may lead to false interpretations being made in biostratigraphic work.

In view of the above it is highly unlikely that a fossil assemblage of pelagic organisms recovered from a marine sediment is a biocoenosis, that is, an assemblage which is representative of the flora which inhabited the surface layers of the ocean above that part of the sea floor which now represents the sampled section. It is much more reasonable to assume the assemblage to be a thanatocoenosis. Equally, it cannot be assumed that an assemblage of calcareous nannofossils, which had a pelagic origin, would provide the same palaeoenvironmental information with regard to temperature, for example, as a fossil assemblage of benthonic organisms. For example, a warm water pelagic flora might be fossilised in association with a cold water benthonic fauna simply as a result of the change in temperature with depth, or as a result of subsurface or ocean bottom current disturbance.

The use of calcareous nannofossils for palaeoenvironmental interpretation is clearly not ideal. It is advantageous to obtain as much information about palaeoenvironmental factors from as many different groups of organisms and other sources as possible before considering the palaeoenvironmental significance of a calcareous nannofossil assemblage.

The information that has been obtained from the study of living coccolithophorids can only be directly applied to the fossil record where the component species of assemblages are the same. Where this does not occur only tentative suggestions can be made from a compilation of all the available information.

MCINTYRE (1967) and MCINTYRE and BÉ (1967) demonstrated that coccoliths are good palaeotemperature indicators for the present oceans and also for the Pleistocene. However, very little is known about the temperature ranges of Tertiary and older coccoliths.

BYBELL and GARTNER (1972) discussed provincialism among mid-Eocene calcareous nannofossils. While calcareous nannofossils are not usually thought of as being provincial and although most workers have noted a general similarity of coeval nannofossil assemblages from widely separated areas, these authors noted some provincialism. For example, the pentolith form, Braarudosphaera, is scarce or lacking in deep water, marine sediments. It is known to be restricted to nearshore environments. BYBELL and GARTNER also noted that genera which have restricted geographical ranges are found almost exclusively in marine sections which were deposited in the hemipelagic realm of shelf seas, in sediments which now form continental rocks.

BUKRY (1974) attempted to use coccoliths as palaeosalinity indicators in sediments from the Black Sea which contained Quaternary coccoliths and some reworked Eocene and Cretaceous forms. He described three stratigraphic units from the distribution of these coccoliths which he said reflected a rising worldwide sea level and an increase in salinity in the Black Sea at the time that marine circulation began through the Bosphorus.

Palaeoenvironmental interpretation of Cretaceous assemblages is more limited. THIERSTEIN (1976) noted that observations can be made concerning the differences between assemblages from different palaeolatitudes and between assemblages from marginal seas and oceanic areas although this may be frustrated by the uneven and geographically scattered sampling of Cretaceous sediments. He noted, for example, that

Nannoconus spp. and Conusphaera mexicana TREJO 1969 are restricted to tropical and subtropical palaeolatitudes in the marginal setting of the Tethyan province. In this case environmental factors seem to have been the controlling factors rather than dissolution, since both of these species have been observed by THIERSTEIN in strongly etched samples.

It is reasonable to assume that calcareous nannoplankton living in Jurassic oceans were influenced by temperature in a similar way to their modern equivalents. However, direct comparison with the floras that have been found to represent different climates in modern oceans is not possible because the species are not the same.

In the present oceans the decline of mean temperature from the equator to the poles is one of the most important determinants of biogeographic distribution. For the Jurassic it is common to stress the equability of climate and to minimise the effects of a temperature gradient. This results, in part, from a general impression of widespread uniformity in Jurassic land floras. However, EDWARDS (1955) claimed that there was a differentiation between northern and southern floras and BARNARD (1973) demonstrated that a "tropical" belt with cycad-like plants and ferns can be distinguished from a "temperate" belt with conifers and ginkgos. AGER (1975) and GORDON (1974) summarised some of the information on the distribution of marine invertebrates which showed that provincialism was a feature of the Mesozoic fauna, recognisable in ammonites, scleractinian corals, foraminifera and belemnites. It seems likely, therefore, that climatic belts did exist in Jurassic time. However, no provincialism was noted in the calcareous nannofossil assemblages examined here.

It is also thought that higher temperatures prevailed during

the Jurassic. RAMSAY (1974) suggested that higher temperatures were the chief factor controlling the rate of accumulation of pelagic (oceanic) carbonate deposition. Higher temperatures would lead to greater solution of calcium carbonate at depth and would, therefore, result in the replacement of calcareous oozes by siliceous ooze. In the Alps RAMSAY noted a remarkable coincidence of the peaks of Jurassic temperature gradient with periods of reduced carbonate deposition.

Salinity has also been cited as a controlling factor in modern calcareous nannoplankton distribution. The salinity of past oceans has been comparatively neglected although HALLAM (1969, 1972) related certain Jurassic facies to salinity conditions and postulated reduced salinity for the Boreal Sea. AGER (1975) noted that "salinity changes have a direct effect on organic productivity, though they are probably more obvious in the fossil record through their effect on organic diversity".

In this study the samples from the Alcanede-Carvalhos Road Section yielded assemblages with a low species diversity as compared with coeval assemblages from the Torres Vedras Section. This is thought to be related to conditions of reduced salinity affecting the former but not the latter area during the Upper Jurassic in Portugal. Text Fig. 20 shows that the low species diversity recorded for this section was accompanied by an increase in the abundance of one species, Tetralithus gothicus DEFLANDRE 1959. However, little is known about the salinity tolerances of modern calcareous nannoplankton and even less is known about this aspect in the fossil record.

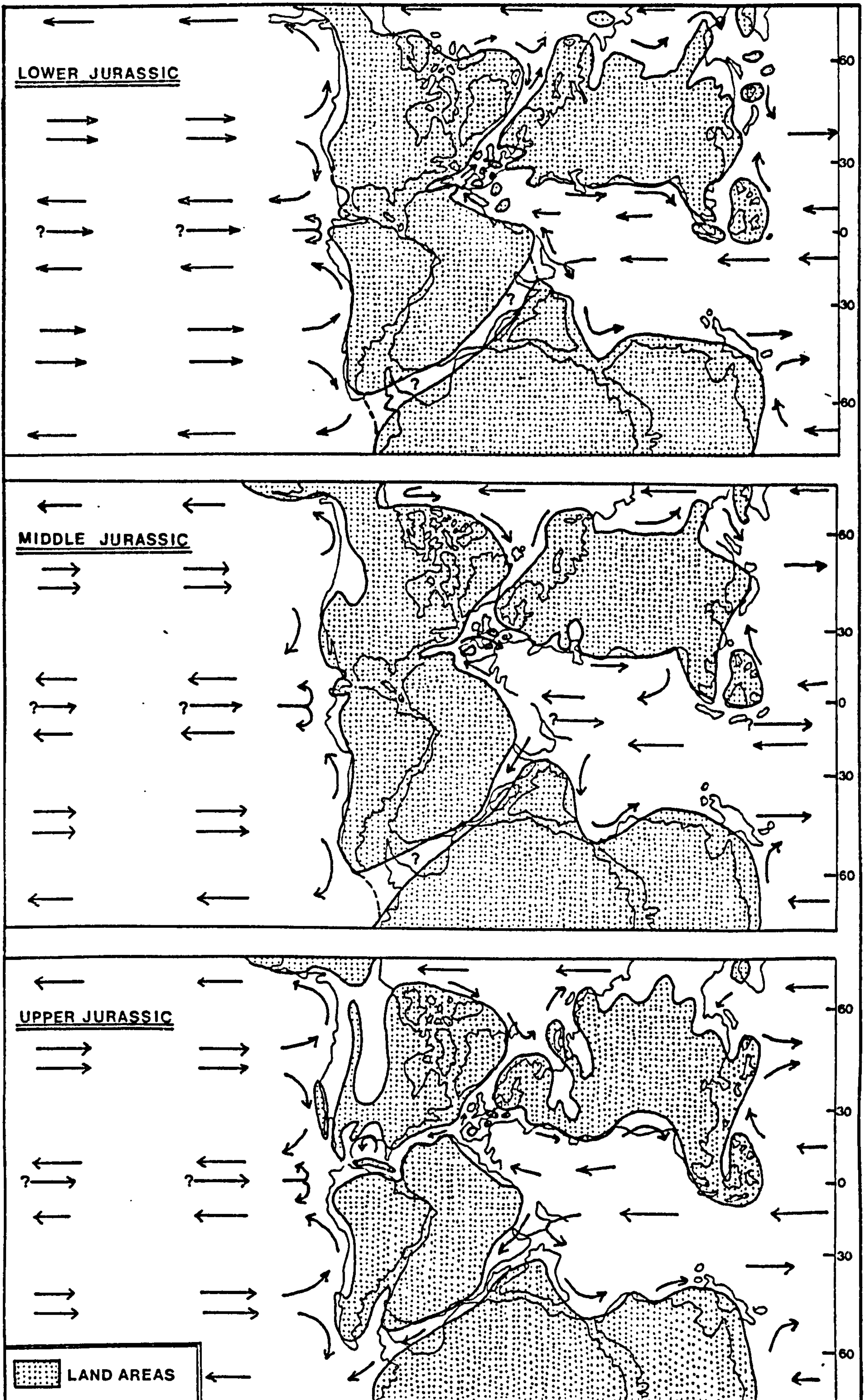
In addition to temperature differentials and salinity changes, GORDON (1974) also noted that physical barriers are important factors

in determining the distribution of the Jurassic biota. These barriers might be land masses or ocean deeps. Oceanic deeps do not present a barrier to the distribution of the living planktonic organisms but may cause their fossil record to be destroyed by calcium carbonate dissolution at depth. Their distribution will, however, be affected by the position of the continents and may be influenced by the system of oceanic currents which build up around the continents.

The rearrangement of the continents for Jurassic time, which is devised mainly from palaeomagnetic evidence, can now be made with some certainty. The maps in Text Fig. 39 are taken from AGER (1975), who superimposed the supposed palaeogeographies of the Lower, Middle and Upper Jurassic upon the rearrangement of the continents proposed by SMITH, BRIDEN and DREWRY (1973).

The existence of climatic belts in the Jurassic suggests a corresponding planetary system of winds. At the present day the main ocean surface currents of the world are predominantly wind driven. AGER (1975), using a uniformitarian comparison, devised the system of ocean surface currents illustrated in Text Fig. 39. This problem has also been considered by GORDON (1974) for the late Jurassic and by BERGGREN and HOLLISTER (1974) for the Atlantic Ocean. Many Jurassic organisms provide support for the suggested circulation pattern because they were influenced by water temperature and this is known to be primarily distributed by surface ocean currents. AGER (1975) discussed the difference between wind-generated surface currents and the deeper ocean currents but noted that the latter are very difficult to determine.

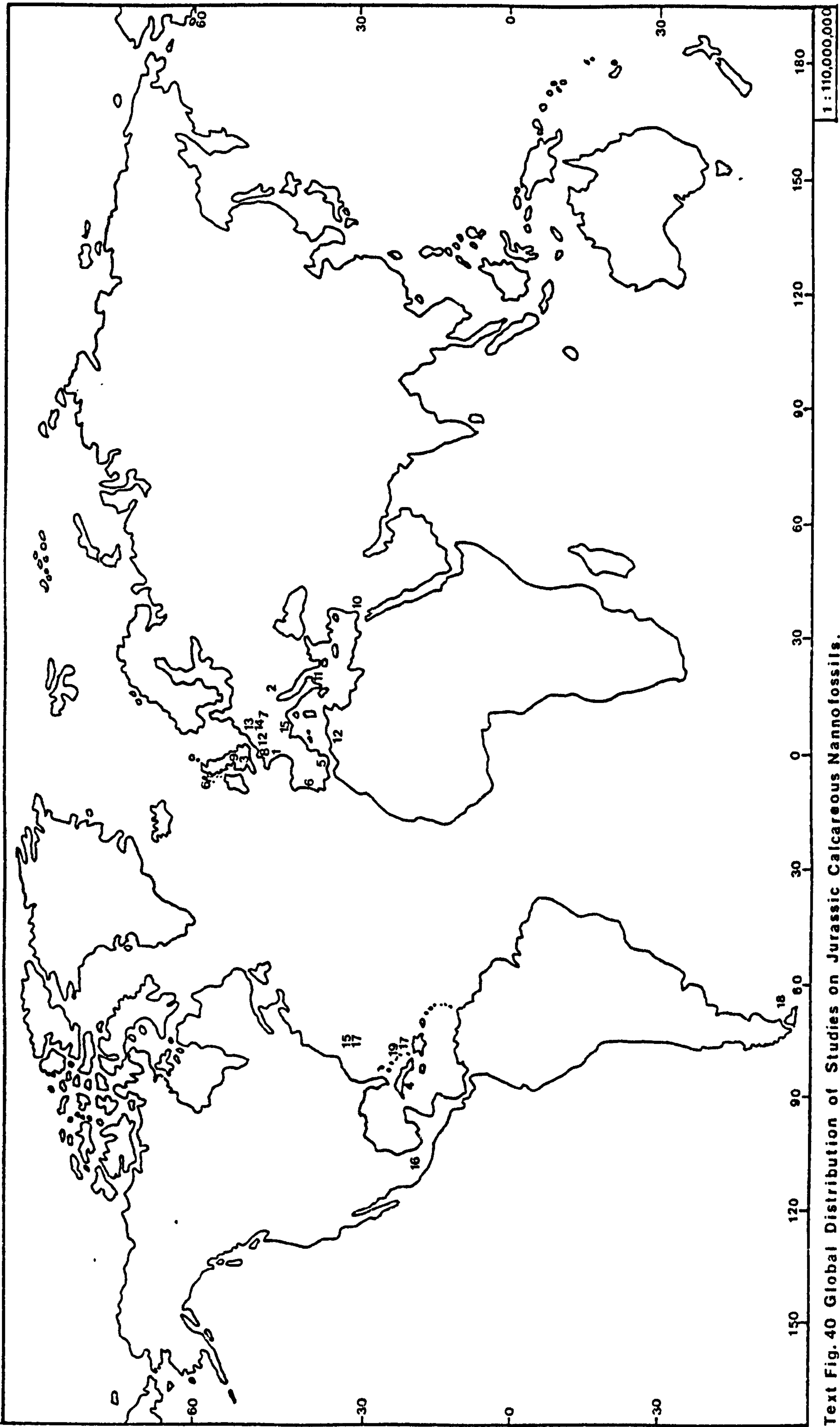
The maps in Text Fig. 39 clearly demonstrate the limitations imposed on the distribution of Jurassic calcareous nannoplankton by land masses. The diagram in Text Fig. 40 also emphasises the very



Text Fig. 39 Continental Reassembly, Palaeogeography and Ocean Surface Currents .
(From AGER,1975)

Key to Text Fig. 40

1. AMEZIEUX (1972) - Paris and Aquitaine Basins
2. BALDI-BEKE (1962) - Hungary
3. BARNARD and HAY (1974) Southern England
ROOD and HAY (1974) and
ROOD, HAY and BARNARD (1971, 1973) North-west France
4. BRONNIMANN (1955) - Cuba
5. GEEL (1966) - South-east Spain
6. HAMILTON (1977) - Portugal
(1978) - Isle of Skye
7. KEUPP (1975, 1976a, 1976b, 1977a, 1977b) - West Germany
8. LEZAUD (1968) - North-west France
9. MEDD (1971) - England and France
10. MOSHKOVITZ and EHRLICH (1976) - Israel and North Sinai
11. NOCERA (1971) - Southern Italy
12. NOEL (1956, 1958, 1965a, 1965b, 1973) - France and Algeria
13. PRINS (1969) - North-west Europe
14. STRADNER (1961, 1963) - North-west Europe
15. THIERSTEIN (1975, 1976) - For localities see THIERSTEIN (1976, Fig.1)
16. TREJO (1969) - Mexico
17. WILCOXON (1972a, 1972b) - Western North Atlantic
18. WISE and WIND (1976) - South-west Atlantic
19. WORSLEY (1971) - Western North Atlantic



Text Fig. 40 Global Distribution of Studies on Jurassic Calcareous Nannofossils.

restricted nature of the record of the distribution of their fossils that is at present available.

Clearly, the scarcity of published data on Jurassic calcareous nannofossils and the geographically restricted areas in which work has so far been undertaken prevents any firm palaeoenvironmental determinations from being made.

At this stage the interpretation of Jurassic calcareous nannofossils is still qualitative. That is to say, has the fossil assemblage been altered by preservation, evolution or palaeoenvironmental factors?

12, CONCLUSIONS

1. Calcareous nannoplankton existed in pre-Jurassic times, possibly as far back as the Permian. Much more work is needed to ascertain the early development of the group. At present it appears that the early stages were represented by very simple forms which are, as yet, of little biostratigraphic use.
2. Species diversity increases during the Jurassic. In the Rhaetian and Hettangian stages only one or two species are recorded. Species diversity reaches a peak in the Callovian-Oxfordian interval; in this study a maximum of 33 species was recorded in the Callovian. Species diversity decreases in the Kimmeridgian and Tithonian and then rises again at the start of the Lower Cretaceous. The fluctuations in species diversity can be related locally to facies and palaeoenvironmental changes.
3. From a comparison of preservation and species diversity in assemblages from the Deep Sea Drilling Project cores with coeval assemblages from exposed, land-based sections, it is clear that core material generally contains a better preserved and more diverse calcareous nannofossil flora.
4. Preservation is an important factor in determining the composition of assemblages. Dissolution and calcium carbonate overgrowth can alter calcareous nannofossil assemblages and confuse the interpretation of fossil remains.
5. The other factors which can alter an assemblage are evolution and

palaeoenvironmental phenomena. Little is known about the latter's effects on Jurassic assemblages since comparison with modern equivalents is not possible.

6. A comparison of the calcareous nannofossil assemblages recovered in this study with published information suggests that Jurassic calcareous nannoplankton were not provincial. This may be a false impression resulting from the limited record of our knowledge about the distribution of the Jurassic flora. At present it results in biostratigraphic schemes having a geographically wide application.
7. The rapid development of calcareous nannofossils and the planktonic mode of life of the living organisms makes these fossils good biostratigraphic and correlatory indicators. Their small size reduces the amount of material required in order to obtain a stratigraphic result as compared with other groups of fossils. This has proved especially useful in the Deep Sea Drilling Project programme where the amount of material available for biostratigraphy is very limited.

The biostratigraphic scheme proposed in this paper subdivides the Jurassic into twelve biozones. It is clear that, although as biostratigraphic indicators for the Jurassic calcareous nannofossils compare favourably with foraminifera and ostracods, the degree of zonal sophistication that can be obtained with them is not as good as that obtainable using ammonites.

13. SYSTEMATIC PALAEONTOLOGY

13.1. Introduction

It is generally accepted that living coccolithophorids belong to the Protophyta. In naming these forms, therefore, the International Code of Botanical Nomenclature (STAFLEU et al 1972) must be used. In the study of fossil forms workers have applied both botanical and zoological nomenclature partly because the true affinity of many forms is still not known. However, in order to maintain uniformity and nomenclatural stability it is desirable to follow a single code.

The International Code of Botanical Nomenclature provides the concepts of organ genus and form genus for the naming of fossil parts whose relationship to a specific plant is not known. These concepts are very useful in the classification of calcareous nannofossils for which little is known of the parent organism.

In the past most authors have attempted to group calcareous nannofossil genera into families based on structural characteristics such as the presence or absence of a stem and the arrangement of the calcite elements. However, studies of modern coccolithophorids have shown that some species produce different kinds of coccoliths at various stages of their life cycle and that some coccospheres are made up of more than one type of coccolith. There seems to be little point in developing a complex taxonomic system at family level especially as the rapid advances being made in the study of this group render most attempts at suprageneric classification obsolete in a short time.

The author follows CHAPMAN and CHAPMAN (1973) in using one family, the Coccolithaceae, for all the coccolith genera encountered in this study. These genera are listed in alphabetical order. Genera which

do not belong to the family Coccolithaceae (Nannoconus for example) are listed at the end of the section under the heading "Incertae Sedis".

For each species a list of synonyms is given which contains the name changes that have been applied to the species up until 1976 and then all the references recorded in 1976, 1977 and 1978. The term "partim" indicates that only part of the description of a previous author is considered by the present author as synonymous with the described species. A short discussion concerning the species is also given and this is followed by a record of the stratigraphic interval and geographical area in which the species was recorded in this work.

Additional information regarding the systematic palaeontology of calcareous nannofossils can be found in LOEBLICH and TAPPAN (1966, 1968, 1969, 1970a, 1970b, 1971, 1973).

13.2. Family Coccolithaceae

Genus Actinozygus GARTNER 1968

Actinozygous geometricus (GORKA 1957) ROOD, HAY & BARNARD 1971

- 1957 Discolithus geometricus GORKA, p. 279; Pl. 4, Fig. 8.
- 1968 Zygolithus geometricus (GORKA 1957) - STRADNER, ADAMIKER and MARESCH, p. 40; Pl. 36; Pl. 37, Fig. 1-4.
- 1969 Corollithion ellipticum BUKRY, p. 40; Pl. 18, Fig. 10, 11.
- 1970b Neococcolithus geometricus (GORKA 1957) - HOFFMANN, p. 182; Pl. 2, Fig. 5, 6; Pl. 3, Fig. 6; Pl. 5, Fig. 5.
- 1971 Ellipsochiastus hexserratus WORSLEY, p. 1308; Pl. 1, Fig. 24-26.
- 1971 Actinozygus geometricus (GORKA 1957) - ROOD, HAY and BARNARD, p. 254; Pl. 1, Fig. 6.
- 1971 Corollithion geometricum (GORKA 1957) - MANIVIT, p. 109; Pl. 5, Fig. 4, 5.

- 1976 Corollithion geometricum (GORKA 1957) MANIVIT 1971 - HILL,
p. 130; Pl. 4, Fig. 19, 20; Pl. 13, Fig. 20.
- 1976 Corollithion geometricum (GORKA 1957) MANIVIT 1971 - WISE and
WIND, p. 272; Pl. 60, Fig. 3, 4.
- 1976 Corollithion ellipticum BUKRY 1969 - WISE and WIND, Pl. 89,
Fig. 9.

Comments:

This species is very rare, perhaps because of its delicate construction, and was not photographed in this study. The author follows the designation of ROOD, HAY and BARNARD (1971) because the genus description for Actinozygus, "elliptical eiffellithalid coccoliths with six to ten symmetrically arranged bars", is more appropriate in its detail than the definition of the genus Corollithion which describes shield construction, a feature that is not easily defined in the light microscope.

Range and Occurrence:

Oxfordian in Portugal.

Lower Oxfordian in Skye.

Genus Annulithus ROOD, HAY & BARNARD 1974

Annulithus arkelli ROOD, HAY & BARNARD 1974

Pl. 8, Fig. 10, 11.

- 1974 Annulithus arkelli ROOD, HAY and BARNARD in BARNARD and HAY, p. 569;
Pl. 1, Fig. 1; Pl. 4, Fig. 1.

Comments:

It is not possible to count the number of elements that make up this simple form as defined in BARNARD and HAY (1974) when examination

is only with the light microscope. The similarity of this species to the Permian form Cricolithus sp. of PIRINI RADRIZZANI (1971) is notable.

Range and Occurrence:

Lower Rhaetian to Hettangian in Great Britain.

Genus Bennocyclus GRÜN, PRINS & ZWEILI 1974

Bennocyclus decussatus GRÜN, PRINS & ZWEILI 1974

Pl. 2, Fig. 6

1974 Bennocyclus decussatus GRÜN, PRINS and ZWEILI, p. 302; Text Fig. 6; Pl. 14; Fig. 4-6.

Comments:

The figured specimen closely resembles the holotype of GRÜN, PRINS and ZWEILI (1974, Pl. 14, Fig. 5). This is a small species which is not easy to recognise under the light microscope.

Range and Occurrence:

Lower Bajocian in Portugal.

Genus Biscutum BLACK 1959

Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975

Pl. 1, Fig. 14; Pl. 6, Fig. 4

1957 Tremalithus ellipticus GORKA, p. 269; Pl. 1, Fig. 11.

1957 Tremalithus melaniae GORKA, p. 270; Pl. 1, Fig. 12.

1957 Tremalithus rhomboidalis GORKA, p. 271; Pl. 2, Fig. 3.

- 1957 Tremalithus enodis GORKA, p. 271; Pl. 2, Fig. 8.
- 1957 Discoaster floridus GORKA, p. 283; Pl. 5, Fig. 11.
- 1959 Biscutum testudinarium BLACK in BLACK and BARNES, p. 325; Pl. 10, Fig. 1.
- 1959 Biscutum castrorum BLACK in BLACK and BARNES, p. 326; Pl. 10, Fig. 2.
- 1960 Coccolithus cf. tenuis KAMPTNER 1937 - CARATINI, p. 42; Pl. 4, Fig. 71, 72.
- 1964 Cribrosphaerella tectiforma REINHARDT, p. 758; Pl. 2, Fig. 4.
- 1965a Paleopontosphaera dubia NOEL, p. 4; Text Fig. 8.
- 1965b Paleopontosphaera dubia NOEL, p. 76; Text Fig. 8; Pl. 7, Fig. 1-13.
- 1965 Coccolithites polycingulatus REINHARDT, p. 39; Pl. 3, Fig. 4.
- 1966 Cribrosphaera tectiforma (REINHARDT 1964) - REINHARDT, p. 30; Pl. 5, Fig. 3; Pl. 12, Fig. 3, 4, 12.
- 1967 Biscutum constans (GORKA 1957) - BLACK, p. 139
- 1967 Watznaueria melaniae (GORKA 1957) - REINHARDT and GORKA, p. 241, 247; Text Fig. 3; Pl. 31, Fig. 10, 14.
- 1968 Maslovella blackii PIENAAR, (partim), p. 366; Pl. 69, Fig. 5.
- 1968 Maslovella pulchra PIENAAR, p. 366; Pl. 69, Fig. 3.
- 1969 Coccolithus melaniae (GORKA 1957) - LYULIEVA and LIPNIK, Pl. 3, Fig. 2.
- 1969 Biscutum melaniae (GORKA 1957) - REINHARDT, p. 936; Pl. 1, Fig. 5.
- 1970 Calyptrolithus tectiforma (REINHARDT 1964) - SHUMENKO, p. 74; Pl. 2, Fig. 1.
- 1971 Biscutum gartneri BLACK, p. 393; Pl. 30, Fig. 2.
- 1975 Biscutum ellipticum (GORKA 1957) - GRÜN and ALLEMANN, p. 154; Text Fig. 3; Pl. 1, Fig. 5-7.
- 1976 Biscutum constans (GORKA 1957) BLACK 1967 - HILL, p. 123; Pl. 1, Fig. 32-37; Pl. 13, Fig. 3, 4.

- 1976a Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975 - KEUPP,
p. 365; Text Fig. 12.
- 1977 Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975 - HAMILTON,
p. 586; Pl. 1, Fig. 7; Pl. 3, Fig. 7.
- 1977a Biscutum ellipticum (GORKA 1957) GRÜN & ALLEMANN 1975 - KEUPP,
p. 26; Pl. 5, Fig. 1-4.

Comments:

This species is found throughout the Jurassic and Cretaceous .
It does not show any significant structural variation during that period.

Range and Occurrence:

Sinemurian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Oxfordian to Lower Cretaceous in the western North Atlantic.

Genus Calyculus NOEL 1973

Calyculus cribrum NOEL 1973

Pl. 3, Fig. 12

- 1973 Calyculus cribrum NOEL, p. 116; Pl. 12, Fig. 1-5.
- 1977 Calyculus cribrum NOEL 1973 - HAMILTON, p. 586; Pl. 1, Fig. 9.

Comments:

In the light microscope this species can be confused with
Calyculus pugnatum GRÜN, PRINS & ZWEILI 1974. In this study the two
species are recorded as Calyculus spp., as can be seen in the range
chart data, since most of the work has been carried out with the light
microscope.

Range and Occurrence:

Sinemurian to Toarcian in Portugal.

Calyculus pugnatum GRÜN, PRINS & ZWEILI 1974

Pl. 3, Fig. 11

1974 Calyculus pugnatum GRÜN, PRINS and ZWEILI, p. 312; Text Fig. 12;
Pl. 19, Fig. 5.

1977 Calyculus pugnatum GRÜN, PRINS & ZWEILI 1974 - HAMILTON, p. 586;
Pl. 1, Fig. 8.

Comments:

The photograph (Pl. 3, Fig. 11) does not clearly illustrate the cruciform structure described by GRÜN, PRINS and ZWEILI (1974). In this study the species is recorded with Calyculus cribrum NOEL 1973 as Calyculus spp. because of the difficulty of identifying the two species in the light microscope.

Range and Occurrence:

Sinemurian to Toarcian in Portugal.

Genus Carinolithus PRINS 1969

Carinolithus superbus (DEFLANDRE 1954) PRINS 1969

Pl. 7, Fig. 19

1954 Rhabdolithus superbus DEFLANDRE in DEFLANDRE and FERT, p. 160;
Text Fig. 93; Pl. 15, Fig. 24, 25.

1969 Carinolithus superbus (DEFLANDRE 1954) - PRINS, p. 552; Pl. 1,
Fig. 7.

1977 Carinolithus superbus (DEFLANDRE 1954) PRINS 1969 - HAMILTON,
p. 586; Pl. 4, Fig. 2, 3.

Comments:

This species is easily identified from the distinctive shape of its stem.

Range and Occurrence:

Lower Toarcian to Upper Bajocian in Portugal.

Genus Crepidolithus NOEL 1965

Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Pl. 7, Fig. 3

1969 Crepidolithus cavus PRINS, Pl. 1, Fig. 4a-c; (invalid).

1973 Crepidolithus cavus PRINS 1969 - ROOD, HAY and BARNARD, p. 375;
Pl. 2, Fig. 5.

1974 Crepidolithus impontus GRÜN["], PRINS and ZWEILI, p. 310; Pl. 21,
Fig. 1-3.

1977 Crepidolithus cavus PRINS 1969 ex ROOD, HAY & BARNARD 1973 -
HAMILTON, p. 586; Pl. 3, Fig. 12.

Comments:

This species may be confused with Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 and Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973. The similarity of the distal views of these species is illustrated in PRINS (1969, Pl. 1). In the proximal view the most prominent feature of Crepidolithus cavus is a central knob or process.

Range and Occurrence:

Sinemurian to Toarcian in Portugal.

Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965

Pl. 3, Fig. 14, 15; Pl. 7, Fig. 4

- 1954 Discolithus crassus DEFLANDRE in DEFLANDRE and FERT, p. 144;
Text Fig. 49; Pl. 15, Fig. 12, 13.
- 1965a Crepidolithus crassus (DEFLANDRE 1954) - NOEL, p. 5; Text
Fig. 17-21.
- 1965b Crepidolithus crassus (DEFLANDRE 1954) - NOEL, p. 85; Text
Fig. 17-21; Pl. 2, Fig. 3-7; Pl. 3, Fig. 1-5.
- 1976 Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 - THIERSTEIN,
Pl. 2, Fig. 6,7.
- 1977 Crepidolithus crassus (DEFLANDRE 1954) NOEL 1965 - HAMILTON,
p. 586; Pl. 3, Fig. 11.

Comments:

This species is large and robust. It tends to be solution resistant, although dissolution may obscure some of its characteristic features such as its median, longitudinal line.

Range and Occurrence:

Sinemurian to Middle Bajocian in Portugal.

Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973

Pl. 7, Fig. 2

- 1969 Crepidolithus crucifer PRINS, p. 551; Pl. 1, Fig. 3a-c; (invalid).
- 1973 Crepidolithus crucifer PRINS 1969 - ROOD, HAY and BARNARD,
p. 374; Pl. 2, Fig. 4.
- 1977 Crepidolithus crucifer PRINS 1969 ex ROOD, HAY & BARNARD 1973 -
HAMILTON, p. 586; Pl. 3, Fig. 10.

Comments:

The figured specimen closely resembles that in BARNARD and HAY (1974, Pl. 4, Fig. 5).

Range and Occurrence:

Sinemurian to Pliensbachian in Portugal.

Genus Cretarhabdus BRAMLETTE & MARTINI 1964 emend. BUKRY 1969

Cretarhabdus sp. 2

Pl. 3, Fig. 10

Comments:

The figured specimen displays the rim features characteristic of the genus Cretarhabdus. There is no regular alignment in the central mesh of this specimen which contrasts markedly with the regular mesh construction seen in specimens of Cretarhabdus sp. 1.

The species is similar to Cretarhabdus conicus BRAMLETTE & MARTINI 1964 except that there are no axial crossbars present in the specimens recorded in this study. BUKRY (1969, Pl. 13, Fig. 7-12) illustrated specimens of Cretarhabdus conicus which show both a regular and an irregular arrangement of the central holes of the mesh. It is not clear, therefore, to what extent the arrangement of the mesh is taxonomically important. Similarly, two of the specimens figured by BUKRY (Pl. 13, Fig. 7,8) do not have prominent axial crossbars. It is possible that the presence or absence of axial crossbars in specimens of Cretarhabdus conicus is related to the preservation of the specimen.

In view of the confusion the author considers that the erection of a new species is not merited.

Range and Occurrence:

Bajocian in Portugal.

Cretarhabdus sp. 1

Pl. 3, Fig. 7-9

Comments:

The regular alignment of the holes in the central mesh of this species is clearly demonstrated in the figured specimens. A full discussion of the taxonomic position of the species is given in the previous description of Cretarhabdus sp. 2.

Range and Occurrence:

Bajocian in Portugal.

Genus Cruciellipsis THIERSTEIN 1971

Cruciellipsis cuvillieri (MANIVIT 1966) THEIRSTEIN 1971

Pl. 8, Fig. 18, 19

- 1966 Coccolithus cuvillieri MANIVIT, p. 268; Text Fig. 2, 3.
- 1969 ?Crucioplacolithus sp. BUKRY and BRAMLETTE, Pl. 3, Fig. C, D;
Pl. 5, Fig. C.
- 1971 Crucioplacolithus pinnatus BLACK, p. 397; Pl. 30, Fig. 5.
- 1971 Cruciellipsis cuvillieri (MANIVIT 1966) - THIERSTEIN, p. 478;
Pl. 5, Fig. 4-8.
- 1972 Crucidiscus andrusovi LAUER in GRÜN["] et al., p. 156; Pl. 25,
Fig. 1, 2.
- 1972 Crucioplacolithus cuvillieri (MANIVIT 1966) - WILCOXON, (partim),
p. 431; Pl. 4, Fig. 4.

- 1977 Cruciellipsis cuvillieri (MANIVIT 1966) THIERSTEIN 1971 -
VERBEEK, p. 105; Pl. 9, Fig. 6.

Comments:

This species is not common in the studied sections. It is easily identified in the light microscope by its wide rim and small central area which is largely filled by an axial cross.

Range and Occurrence:

Tithonian? to Lower Cretaceous in the western North Atlantic.

Genus Crucirhabdus PRINS 1969

Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Pl. 7, Fig. 13

- 1969 Crucirhabdus primulus PRINS, p. 548; (invalid).
- 1969 Crucirhabdus primulus var. nannus PRINS, p. 551; Pl. 1, Fig. 1; Pl. 2, Fig. 1; Pl. 3, Fig. 1; (invalid).
- 1969 Crucirhabdus primulus var. primulus PRINS, (as Crucirhabdus primulus s.s.), p. 552; Pl. 2, Fig. 2; (invalid).
- 1969 Crucirhabdus primulus var. striatulus PRINS, p. 554; Pl. 3, Fig. 3; (invalid).
- 1969 Crucirhabdus primulus var. orbicularis PRINS, Pl. 2, Fig. 3a; (invalid).
- 1973 Crucirhabdus primulus PRINS 1969 - ROOD, HAY and BARNARD, p. 367; Pl. 1, Fig. 1, 2.
- 1976 Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 - THIERSTEIN, Pl. 2, Fig. 1, 2.
- 1977 Crucirhabdus primulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 - HAMILTON, p. 586; Pl. 4, Fig. 4.

Comments:

This is a very small, delicately constructed species which is only rarely found in its complete form. Thus, no scanning electron micrograph is available from this study. The species is easily recognised in side view in the light microscope from the characteristic shape of its base and spine. The specimen figured in Pl. 7, Fig. 13 is clearly comparable to the paratype of ROOD, HAY and BARNARD (1973, Pl. 1, Fig. 2).

Range and Occurrence:

Sinemurian to Pliensbachian in Portugal.

Genus Cyclagelosphaera NOEL 1965

Cyclagelosphaera margereli NOEL 1965

Pl. 1, Fig. 10, 11

- 1965 Coccolithus sp. BLACK, p. 133; Text Fig. 7.
- 1965a Cyclagelosphaera margereli NOEL, p. 8; Text Fig. 45, 46, 48.
- 1965b Cyclagelosphaera margereli NOEL (partim), p. 130; Text Fig. 44-46; Pl. 17, Fig. 4-9; Pl. 18, Fig. 1, 2; Pl. 20, Fig. 2.
- 1966 Tergestiella barnesae (BLACK 1959) REINHARDT 1964 - REINHARDT, (partim), p.15; Text Fig. 2; Pl. 1, Fig. 1, 2.
- 1968 Markalius circumradiatus (STOVER 1966) - PERCH-NIELSEN, (partim), p. 73; Text Fig. 36; Pl. 25, Fig. 2-7.
- 1969 Tergestiella margereli (NOEL 1965) - SHUMENKO, p. 69; Pl. 1, Fig. 3.
- 1971 Tergestiella? reinhardti (PERCH-NIELSEN 1968) - REINHARDT, p. 29; Text Fig. 24; Pl. 1, Fig. 6.
- 1973 Cyclagelosphaera casarubrensis BLACK, p. 76; Pl. 25, Fig. 1-3.

- 1973 Cyclagelosphaera puncta BLACK, p. 76; Pl. 25, Fig. 13.
- 1973 Cyclagelosphaera shenleyensis BLACK, p. 78; Text Fig. 39;
Pl. 25, Fig. 10.
- 1976a Cyclagelosphaera margereli NOEL 1965 - KEUPP, p. 366; Text
Fig. 7-9.
- 1976b Cyclagelosphaera margereli NOEL 1965 - KEUPP, Pl. 1, Fig. a;
Pl. 2, Fig. c; Pl. 3, Fig. c?
- 1976 Cyclagelosphaera margereli NOEL 1965 - HILL, p. 136; Pl. 14,
Fig. 3.
- 1976 Cyclagelosphaera margereli NOEL 1965 - MOSHKOVITZ and EHRLICH,
p. 13; Pl. 5, Fig. 1-6, 10.
- 1976 Cyclagelosphaera margereli NOEL 1965 - WISE and WIND, p. 272;
Pl. 31, Fig. 1, 2; Pl. 73, Fig. 8; Pl. 85, Fig. 6; Pl. 87, Fig. 1,
2, 5; Pl. 88, Fig. 10.
- 1977a Cyclagelosphaera margereli NOEL 1965 - KEUPP, p. 29; Pl. 1,
Fig. 1, 2; Pl. 2, Fig. 1; Pl. 6, Fig. 1-8; Pl. 7, Fig. 1-6;
Pl. 16, Fig. 1; Pl. 17, Fig. 6.
- 1977b Cyclagelosphaera margereli NOEL 1965 - KEUPP, p. 104; Pl. 8,
Fig. 1, 5.
- 1977 Cyclagelosphaera margereli NOEL 1965 - VERBEEK, p. 82; Pl. 4,
Fig. 2.
- 1978 Cyclagelosphaera margereli NOEL 1965 - HAMILTON, p. 33; Pl. 1,
Fig. 14.

Comments:

This is a long ranging species whose construction does not alter throughout its range between the Middle Jurassic and the Maestrichtian.

"

The synonym list of GRUN and ALLEMANN (1975) provides a good illustration

of the broad stratigraphic range and the wide geographic distribution of this species.

Range and Occurrence:

Bajocian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Lower Cretaceous in the western North Atlantic.

Genus Diazomatolithus NOEL 1965

Diazomatolithus lehmani NOEL 1965

Pl. 7, Fig. 11, 12

1965 Diazomatolithus lehmani NOEL, p. 96; Text Fig. 25-27; Pl. 6, Fig. 6-10.

1974 Diazomatolithus lehmani NOEL 1965 - BARNARD and HAY, Pl. 2, Fig. 11; Pl. 5, Fig. 10.

Comments:

In the light microscope the presence of a central hole, which seems to vary in size, and the strong imbrication of the plates distinguishes these small specimens as belonging to the genus Diazomatolithus. Identification at species level is not easy and may result in confusion between Diazomatolithus lehmani and Diazomatolithus subbeticus GRÜN & ALLEMANN 1975.

Range and Occurrence:

Upper Toarcian to Bathonian in Portugal.

Callovian? to Lower Cretaceous in the western North Atlantic.

Diazomatolithus sp.

Pl. 6, Fig. 6; Pl. 8, Fig. 12

Comments:

The figured specimens show some similarity in their plate arrangement to members of the genus Diazomatolithus NOEL 1965. They are notable for their large size, contrasting with the smaller specimens of Diazomatolithus lehmani NOEL 1965, but are not common.

Range and Occurrence:

Bathonian to Callovian in Portugal.

Oxfordian in the western North Atlantic.

Genus Discorhabdus NOEL 1965

Discorhabdus biperforatus ROOD, HAY & BARNARD 1973

Pl. 5, Fig. 7, 8

1973 Discorhabdus biperforatus ROOD, HAY and BARNARD, p. 381;

Pl. 3, Fig. 7.

1976 Discorhabdus sp. 1 MOSHKOVITZ and EHRLICH, (partim.), p. 14;

Pl. 6, Fig. 11.

Comments:

This species is not common and is not easy to identify in the light microscope unless the perforations are exposed.

Range and Occurrence:

Bathonian/Callovian? to Tithonian in the western North Atlantic.

Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968

Pl. 5, Fig., 3-6, 9, 12; Pl. 8, Fig. 9

- 1957 Tremalithus ignotus GORKA, p. 272; Pl. 2, Fig. 9.
- 1965 Biscutum tredinale REINHARDT, p. 32; Text Fig. 2; Pl. 1, Fig. 3.
- 1965b "Embase de Discorhabdus" NOEL, p. 148; Text Fig. 59, 60; Pl. 23, Fig. 2-5, 8-13.
- 1966 Biscutum testudinarium BLACK 1959 - REINHARDT, p. 30; Pl. 19, Fig. 1.
- 1967 Biscutum ignotum (GORKA 1957) - REINHARDT and GORKA, p. 245; Pl. 31, Fig. 9, 13.
- 1968 Discorhabdus ignotus (GORKA 1957) - PERCH-NIELSEN, p. 81; Text Fig. 41, 42; Pl. 28, Fig. 6-8.
- 1968 Podorhabdus? sp. LEZAUD, Pl. 1, Fig. 14, 15.
- 1969 Bidiscus rotatorius BUKRY, p. 27; Pl. 7, Fig. 5-9.
- 1969 Bidiscus monocavus BUKRY, p. 27; Pl. 7, Fig. 3, 4.
- 1970 Coccolithus sp. BARTOLINI, Pl. 3, Fig. 5.
- 1970a Bidiscus ignotus (GORKA 1957) - HOFFMANN, p. 862; Pl. 7, Fig. 1.
- 1970 Discorhabdus bellis NOEL, p. 89; Pl. 32, Fig. 8, 11-13.
- 1970 Discorhabdus testudinarium (BLACK 1959) - SHUMENKO, p. 72; Pl. 1, Fig. 3, 4.
- 1971 Bidiscus gorkae BLACK, p. 392; Pl. 30, Fig. 1.
- 1971 Discorhabdus sp. ROOD, HAY and BARNARD, p. 267; Pl. 4, Fig. 8.
- 1972 Bidiscus bifrons BLACK, p. 24; Pl. 1, Fig. 1, 2.
- 1972 Bidiscus hintonensis BLACK, p. 25; Pl. 1, Fig. 4-6.
- 1972 Bidiscus bramlettei BLACK, p. 25; Pl. 1, Fig. 3.
- 1976 Bidiscus gorkae BLACK 1971 - BURNS, p. 280; Pl. 1, Fig. 2.
- 1976a Bidiscus ignotus (GORKA 1957) HOFFMANN 1970 - KEUPP, p. 364; Text Fig. 13-15.

- 1976 Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968 - HILL,
p. 137; Pl. 6, Fig. 12-18; Pl. 14, Fig. 4, 5.
- 1976 Discorhabdus sp. 1 MOSHKOVITZ and EHRLICH, (partim), p. 14;
Pl. 6, Fig. 10.
- 1976 Discorhabdus sp. 2 MOSHKOVITZ and EHRLICH, p. 15; Pl. 8, Fig. 1-6.
- 1977 Discorhabdus ignotus (GORKA 1957) PERCH-NIELSEN 1968 - HAMILTON,
p. 586; Pl. 2, Fig. 1-11; Pl. 4, Fig. 10, 11.
- 1977a Bidiscus ignotus (GORKA 1957) HOFFMANN 1970 - KEUPP, p. 23;
Pl. 3, Fig. 1-6.
- 1977 Bidiscus ignotus (GORKA 1957) HOFFMANN 1970 - VERBEEK, p. 80;
Pl. 3, Fig. 9.
- 1977 Bidiscus rotatorius BUKRY 1969 - VERBEEK, p. 80; Pl. 3, Fig. 10.

Comments:

This is a long ranging species which shows some slight variation in structural detail during its range throughout the Jurassic and Cretaceous. It is here included in the genus Discorhabdus and not in the genus Bidiscus BUKRY 1969 because NOEL's description has priority and is adequate in its detail.

Range and Occurrence:

Sinemurian to Lower Kimmeridgian in Portugal.

Callovian to Lower Cretaceous in the western North Atlantic.

Discorhabdus jungi NOEL 1965

Pl. 5, Fig. 15; Pl. 7, Fig. 20

- 1965b Discorhabdus jungi NOEL, p. 144; Pl. 22, Fig. 5.
- 1974 Discorhabdus jungi NOEL 1965 - BARNARD and HAY, Pl. 3, Fig. 5;
Pl. 6, Fig. 4.

Comments:

The figured specimens clearly resemble previous illustrations of this rare but very distinctive rhabdolith.

Range and Occurrence:

Lower to Middle Bathonian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Lower Oxfordian in the western North Atlantic.

Discorhabdus patulus (DEFLANDRE 1954) NOEL 1965

Pl. 7, Fig. 17

1954 Rhabdolithus patulus DEFLANDRE in DEFLANDRE and FERT, p. 162;

Text Fig. 97, 98; Pl. 15, Fig. 40-45.

1965b Discorhabdus patulus (DEFLANDRE 1954) - NOEL, p. 141; Text

Fig. 55-57; Pl. 21, Fig. 6-8, 10, 11; Pl. 22, Fig. 1, 2, 7, 9, 10.

1976 Discorhabdus patulus (DEFLANDRE 1954) NOEL 1965 - MOSHKOVITZ

and EHRLICH, p. 13; Pl. 6, Fig. 8, 9.

1977 Discorhabdus patulus (DEFLANDRE 1954) NOEL 1965 - HAMILTON,

p. 586; Pl. 1, Fig. 12; Pl. 4, Fig. 5.

Comments:

This species is best identified from its stem characteristics, the stem being quite wide near the basal disc and becoming thinner towards the other end. The cross bar at this end of the stem is a common feature.

Range and Occurrence:

Upper Toarcian to Bathonian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Oxfordian in the western North Atlantic.

Discorhabdus tubus NOEL 1965

Pl. 7, Fig. 18

1965b Discorhabdus tubus NOEL, p. 145; Pl. 21, Fig. 4, 15.

1977 Discorhabdus tubus NOEL 1965 - HAMILTON, p. 586; Pl. 4, Fig. 1.

Comments:

The cylindrical, axial stem is the main distinguishing feature of this fairly uncommon species.

Range and Occurrence:

Upper Toarcian to Middle Bathonian in Portugal.

Lower Oxfordian in the western North Atlantic.

Discorhabdus sp.

Pl. 5, Fig. 10, 11

Comments:

The figured specimens show the characteristic structures of the genus Discorhabdus. They differ from Discorhabdus ignotus (CORKA 1957) PERCH-NIELSEN 1968 in that they are larger and in the greater diameter of the central area and axial stem.

Although specimens of this type are common in the studied sections they are not given the status of a new species because of the uncertainty of the nature of the complete stem and because no proximal view was recorded.

Range and Occurrence:

Bajocian to Callovian in Portugal.

Genus Ellipsagelosphaera NOEL 1965

Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968

Pl. 1, Fig. 1, 2

- 1963 Coccolithus britannicus STRADNER, p. 176; Pl. 1, Fig. 7.
- 1964 Watznaueria britannica (STRADNER 1963) - REINHARDT, p. 753;
Text Fig. 5; Pl. 2, Fig. 3.
- 1964 Watznaueria communis REINHARDT, p. 756; Text Fig. 6; Pl. 2, Fig. 5.
- 1965a Ellipsagelosphaera frequens NOEL, (partim), p. 8; Text Fig. 38.
- 1965a Ellipsagelosphaera lucasi NOEL, p. 8; Text Fig. 40, 41.
- 1965b Ellipsagelosphaera frequens NOEL, (partim), p. 119; Text Fig. 38;
Pl. 11, Fig. 7; Pl. 12, Fig. 1-7, 9, 10; Pl. 13, Fig. 5, 7, 8, 10.
- 1965b Ellipsagelosphaera lucasi NOEL (partim), p. 126; Text Fig. 41,
42; Pl. 11, Fig. 1-6.
- 1968 Ellipsagelosphaera communis (REINHARDT 1964) - PERCH-NIELSEN,
p. 70; Text Fig. 33c, d.
- 1968 Ellipsagelosphaera britannica (STRADNER 1963) - PERCH-NIELSEN,
p. 71.
- 1971 Ellipsagelosphaera gephyrocapsoides BLACK, p. 399; Pl. 30, Fig. 7.
- 1971 Ellipsagelosphaera sp. NOCERA, Pl. 1, Fig. 6.
- 1976a Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968
- KEUPP, p. 367; Text Fig. 2, 5.
- 1976 Watznaueria communis REINHARDT 1964 - WISE and WIND, p. 272;
Pl. 86, Fig. 1, 2, 5; Pl. 88, Fig. 7.
- 1976 Watznaueria britannica (STRADNER 1963) REINHARDT 1964 - WISE
and WIND, p. 272; Pl. 86, Fig. 4; Pl. 88, Fig. 8.
- 1977a Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN
1968 - KEUPP, p. 34; Pl. 8, Fig. 1-6.

- 1978 Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN
1968 - HAMILTON, p. 33; Pl. 1, Fig. 1, 4.

Comments:

The author follows GRÜN and ALLEMANN (1975) in placing the species in the genus Ellipsagelosphaera and not in the genus Watznaueria REINHARDT 1964 because the specimens possess a central tube of elements which is lacking in members of the latter genus.

The author considers the species Ellipsagelosphaera communis to be a junior synonym of Ellipsagelosphaera britannica. She does not consider that subdivision into two separate species on the basis of the size of the central area and its spanning bridge is valid. These features are very variable and are hard to define except by comparison.

Finally, the author agrees with the suggestion of GRÜN and ALLEMANN that heavy corrosion of the species may produce the form which is known as Calolithus martelae NOEL 1965. The latter is not therefore recognised as a separate species.

Range and Occurrence:

Lower Toarcian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian/Callovian? to Lower Cretaceous in the western North Atlantic.

Ellipsagelosphaera crucicentralis MEDD 1971

Pl. 2, Fig. 7-9; Pl. 8, Fig. 8

- 1971 Ellipsagelosphaera crucicentralis MEDD, p. 829; Pl. 1, Fig. 1, 2.

Comments:

The figured specimens closely resemble those described by MEDD although the oblique alignment of the central cross, defined as being characteristic in the original description, is not a prominent feature of the forms found in this study.

Range and Occurrence:

Bathonian to Callovian in Portugal.

Upper Callovian in Great Britain.

Ellipsagelosphaera keftalrempti GRUN & ALLEMANN 1975

Pl. 1, Fig. 3, 4, 12.

1965b Ellipsagelosphaera frequens NOEL, (partim), p. 119; Pl. 12, Fig. 8.

1966 Watznaueria sp. aff. W. communis REINHARDT 1964 - REINHARDT, p. 19; Pl. 4, Fig. 1.

1966 Coccolithus britannicus STRADNER 1963 - MARESCH, (partim), Pl. 2, Fig. 2.

1968 Ellipsagelosphaera frequens NOEL 1965 - LEZAUD, p. 16; Pl. 1, Fig. 12.

1969 Ellipsagelosphaera sp. BARBIERI and MEDIOLI, p. 733; Pl. 48, Fig. 6a.

1971 Ellipsagelosphaera frequens NOEL 1965 - NOCERA, (partim), p. 429; Pl. 1, Fig. 4, 5.

1971 Ellipsagelosphaera coronata (GARTNER 1968) - BLACK, p. 398; Pl. 30, Fig. 6.

1971 Ellipsagelosphaera fossacincta BLACK, p. 399; Pl. 30, Fig. 8.

1972 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - LAUER
in GRUN et al., (partim), p. 154; Pl. 26, Fig. 5.

- 1975 Ellipsagelosphaera sp. KEUPP, Text Fig. 4.
- 1975 Ellipsagelosphaera keftalrempti GRÜN and ALLEMANN, p. 161;
Text Fig. 7; Pl. 2, Fig. 5,6.
- 1976b Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - KEUPP,
Pl. 2, Fig. b; Pl. 3, Fig. e.
- 1976 Watznaueria sp. WISE and WIND, Pl. 86, Fig. 6.
- 1977a Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 - KEUPP,
p. 36; Pl. 1, Fig. 3; Pl. 9, Fig. 1-5; Pl. 10, Fig. 1-6.
- 1977b Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 - KEUPP,
p. 104; Pl. 8, Fig. 4.
- 1977 Watznaueria communis REINHARDT 1964 - VERBEEK, p. 85; Pl. 4,
Fig. 7.
- 1978 Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1975 - HAMILTON,
p. 33; Pl. 1, Fig. 2, 5.

Comments:

A full list of synonyms is given for this species since specimens of this species have often been included under other species by previous authors. Ellipsagelosphaera keftalrempti is readily distinguished from Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968 by its small size, its small central area and the absence of a bridge in the central area. The presence of the central tube of elements distinguishes this species from Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968.

Range and Occurrence:

Lower Bajocian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian/Callovian? to Lower Cretaceous in the western North Atlantic.

Ellipsagelosphaera sp.

Comments:

Small specimens with this well known rim which cannot be identified at species level because of their size are assigned to the genus Ellipsagelosphaera on the basis of their characteristic rim structure. Their stratigraphic distribution suggests that they could be the ancestral forms of Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968.

Range and Occurrence:

Upper Pliensbachian to Middle Toarcian in Portugal.

Genus Ethmorhabdus NOEL 1965

Ethmorhabdus gallicus NOEL 1965

Pl. 4, Fig. 5, 6

- 1965b Ethmorhabdus gallicus NOEL, p. 110; Text Fig. 33, 34; Pl. 10, Fig. 1-5.
- 1976 Ethmorhabdus gallicus NOEL 1965 - THIERSTEIN, Pl. 2, Fig. 15-18.
- 1976 Ethmorhabdus gallicus NOEL 1965 - WISE and WIND, p. 272; Pl. 77, Fig. 5, 6; Pl. 88, Fig. 1, 2.
- 1978 Ethmorhabdus gallicus NOEL 1965 - HAMILTON, p. 33; Pl. 1, Fig. 8.

Comments:

When complete or even partially complete this species is easy to identify in the light microscope because of its central mesh and characteristically narrow rim.

Range and Occurrence:

Callovian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Oxfordian in the western North Atlantic.

Genus Hemipodorhabdus BLACK 1971

Hemipodorhabdus gorkae (REINHARDT 1969) GRÜN & ALLEMANN 1975

Pl. 6, Fig. 2, 3

- 1969 Podorhabdus gorkae REINHARDT, p. 933; Pl. 1, Fig. 1, 2.
1971 Hemipodorhabdus latiforatus BLACK, p. 404; Pl. 31, Fig. 6.
1972 Hemipodorhabdus biferatus BLACK, (partim), p. 37; Pl. 10, Fig. 7.
1975 Hemipodorhabdus gorkae (REINHARDT 1969) - GRÜN and ALLEMANN, p. 171.

Comments:

Although GRÜN and ALLEMANN (1975) did not figure this species in their text or plates, good illustrations may be found in the other references given here. The figured specimens (Pl. 6, Fig. 2, 3) closely resemble these illustrations.

Range and Occurrence:

Callovian/Oxfordian? in the western North Atlantic.

Genus Hexapodorhabdus NOEL 1965

Hexapodorhabdus cuvillieri NOEL 1965

Pl. 4, Fig. 2, 3

- 1965b Hexapodorhabdus cuvillieri NOEL, p. 105; Pl. 9, Fig. 4-6.
1970 Podorhabdus cuvillieri (NOEL 1965) - REINHARDT, p. 86; Text Fig. 105.

- 1976 Hexapodorhabdus cuvillieri NOEL 1965 - MOSHKOVITZ and EHRLICH,
p. 11; Pl. 2, Fig. 14, 15.
- 1976 Hexapodorhabdus cuvillieri NOEL 1965 - WISE and WIND, p. 272;
Pl. 81, Fig. 5.
- 1978 Hexapodorhabdus cuvillieri NOEL 1965 - HAMILTON, p. 33; Pl. 1,
Fig. 9.

Comments:

Although the figured specimens (Pl. 4, Fig. 2, 3) do not show the characteristic six holes surrounding a hollow stem, it is clear that in both cases one of the holes is obscured either by foreign material or by the angle in which the coccolith is lying.

Range and Occurrence:

Bajocian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Oxfordian in the western North Atlantic.

Genus Manivitella THIERSTEIN 1971

Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971

Pl. 6, Fig. 10-12

Not 1965 Cricolithus pemmatoideus DEFLANDRE in MANIVIT, p. 192;

Pl. 2, Fig. 8.

1966 Cyclolithus gronosus STOVER, (partim), p. 140; Pl. 1, Fig. 1, 2;
Pl. 8, Fig. 1.

1969 Apertapetra gronosa (STOVER 1966) - BUKRY, p. 26; Pl. 6, Fig. 6.

1971 Manivitella pemmatoidea (DEFLANDRE in MANIVIT 1965) - THIERSTEIN,
p. 480; Pl. 5, Fig. 1-3.

1976 Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971 -
HILL, p. 144; Pl. 8, Fig. 15-17; Pl. 14, Fig. 18, 19.

1977 Manivitella pemmatoidea (DEFLANDRE 1965) THIERSTEIN 1971 -
VERBEEK, p. 83; Pl. 4, Fig. 4.

Comments:

This species may be confused with Tubodiscus verenae THIERSTEIN 1973 emend. GRUN & ALLEMANN 1975. The latter authors clarified the differentiation by restricting Manivitella pemmatoidea to specimens which have two cycles of elements and Tubodiscus verenae to specimens with three cycles of elements which may include a proximally extending central tube.

Range and Occurrence:

Upper Callovian/Oxfordian? to Lower Cretaceous in the western North Atlantic.

Genus Markalius BRAMLETTE & MARTINI 1964

Markalius inversus (DEFLANDRE 1954) BRAMLETTE & MARTINI 1964

Pl. 6, Fig. 5; Pl. 7, Fig. 6

1954 Cyclococcolithus leptoporous MURRAY & BLACKMANN 1898 var.
inversus DEFLANDRE in DEFLANDRE and FERT, (partim), p. 150;
Pl. 9, Fig. 4, 5.

1964 Markalius inversus (DEFLANDRE 1954) - BRAMLETTE and MARTINI,
p. 302; Pl. 2, Fig. 4-9; Pl. 7, Fig. 2.

1966 Coccolithites circumradiatus STOVER, p. 138; Pl. 5, Fig. 2-4,
Pl. 9, Fig. 10.

1968 Markalius circumradiatus (STOVER 1966) - PERCH-NIELSEN, (partim),
p. 73; Pl. 26, Fig. 1, 2.

- 1969 Cyclagelosphaera? chronolitha BUKRY, p. 29; Pl. 9, Fig. 2-4.
- 1975 Markalius inversus (DEFLANDRE 1954) BRAMLETTE & MARTINI 1964 -
" GRUN and ALLEMANN, p. 199; Text Fig. 33; Pl. 8, Fig. 6.

Comments:

This species had a very limited occurrence in the studied sections.

Range and Occurrence:

Lower Cretaceous in the western North Atlantic.

Genus Octopodorhabdus NOEL 1965

Octopodorhabdus decussatus (MANIVIT 1959) ROOD, HAY & BARNARD 1971

Pl. 4, Fig. 4

- 1959 Discolithus decussatus MANIVIT, p. 14; Pl. 1, Fig. 7.
- 1963 Rhabdolithus decussatus (MANIVIT 1959) - STRADNER, p. 175;
Pl. 5, Fig. 8, 8a.
- 1971 Octopodorhabdus decussatus (MANIVIT 1959) - ROOD, HAY and
BARNARD, p. 262; Pl. 3, Fig. 4.

Comments:

This species is rare. Although the figured specimen is partially obscured it is clearly similar to the specimen figured in ROOD, HAY and BARNARD (1971).

Range and Occurrence:

Middle Bajocian to Middle Bathonian in Portugal.

Oxfordian in the western North Atlantic.

Genus Parhabdolithus DEFLANDRE 1952

Parhabdolithus embergeri (NOEL 1958) STRADNER 1963

Pl. 6, Fig. 13, 14; Pl. 8, Fig. 16, 17

- 1958 Discolithus embergeri NOEL, p. 164; Pl. 1, Fig. 5-8.
- 1963 Parhabdolithus embergeri (NOEL 1958) - STRADNER, p. 174;
Pl. 4, Fig. 1.
- 1976 Parhabdolithus embergeri (NOEL 1958) STRADNER 1963 - HILL,
p. 147; Pl. 9, Fig. 30, 31; Pl. 10, Fig. 1-5.
- 1976 Parhabdolithus embergeri (NOEL 1958) STRADNER 1963 - BURNS,
p. 290; Pl. 4, Fig. 2.
- 1976 Parhabdolithus embergeri (NOEL 1958) STRADNER 1963 - WISE and
WIND, p. 272; Pl. 71, Fig. 7, 8.
- 1977 Parhabdolithus embergeri (NOEL 1958) STRADNER 1963 - VERBEEK,
p. 90; Pl. 5, Fig. 11, ?12.

Comments:

"
The publications of GRÜN and ALLEMANN (1975) and HILL (1976)
provide a thorough review of the literature concerning this species.
Parhabdolithus embergeri is easily identified in the light microscope
by its large size and the distinct appearance of its central structure.

Range and Occurrence:

Middle Kimmeridgian to Lower Cretaceous in the western North
Atlantic.

Parhabdolithus liasicus DEFLANDRE 1952

Pl. 7, Fig. 14

- 1952 Parhabdolithus liasicus DEFLANDRE, p. 466; Text Fig. 362 J-M.

- 1969 Parhabdolithus longispinus PRINS, Pl. 2, Fig. 5.
- 1969 Parhabdolithus elongatus PRINS, Table 1.
- 1976 Parhabdolithus liasicus DEFLANDRE 1952 - THIERSTEIN, Pl. 2, Fig. 4, 5.
- 1977 Parhabdolithus liasicus DEFLANDRE 1952 - HAMILTON, p. 587; Pl. 4, Fig. 7, 8.

Comments:

The side view of this species, showing the basal disc and stem, is better known and more characteristic than the polar view. This may result from the fact that the original description figured this aspect. The species is not well known in polar view although the illustration in THIERSTEIN (1976) is good.

Range and Occurrence:

Sinemurian to Pliensbachian in Portugal.

Parhabdolithus marthae DEFLANDRE 1954

Pl. 5, Fig. 13; Pl. 7, Fig. 15, 16

- 1954 Parhabdolithus marthae DEFLANDRE in DEFLANDRE and FERT, p. 163; Text Fig. 101, 102 and ?103; Pl. 15, Fig. 22, 23.
- 1965a Parhabdolithus robustus NOEL, p. 5; Text Fig. 24.
- 1965b Parhabdolithus robustus NOEL, p. 95; Text Fig. 24; Pl. 4, Fig. 1, 2.
- 1977 Parhabdolithus marthae DEFLANDRE 1954 - HAMILTON, p. 587; Pl. 1, Fig. 10; Pl. 4, Fig. 6.

Comments:

This species is small but it is easily recognised from its rotund body and short robust stem. As with Parhabdolithus liasicus DEFLANDRE 1952, the characteristic view of this species is from the side.

Range and Occurrence:

Sinemurian in Portugal.

Parhabdolithus sp.

Pl. 3, Fig. 5, 6; Pl. 7, Fig. 8

1977 Ethmorhabdus sp. aff. Ethmorhabdus gallicus NOEL 1965 -
HAMILTON, p. 587; Pl. 1, Fig. 4-6; Pl. 3, Fig. 4, 5.

Comments:

The rim structure of the figured specimens (Pl. 3, Fig. 5, 6), a single layer of upright elements, is not typical of the genus Ethmorhabdus NOEL 1965 (HAMILTON 1977). The rims of members of the genus Ethmorhabdus are made up of a double series of calcite elements. The specimens are here included in the genus Parhabdolithus DEFLANDRE 1952. They show some similarity to the Cretaceous species Parhabdolithus asper (STRADNER 1963) REINHARDT 1967.

Range and Occurrence:

Sinemurian to Upper Toarcian in Portugal.

Genus Perrisocyclus BLACK 1971

Perrisocyclus sp.

Pl. 4, Fig. 13-15

Comments:

The figured specimens were placed in the genus Perrisocyclus BLACK 1971 because they have a two layered podorhabdid rim surrounding a wide, perforated central area and a hollow spine. They are similar to specimens of Perrisocyclus fenestratus (STOVER 1966) BLACK 1971 but

do not possess the two concentric cycles of holes in the central area with "8-16 in the outer ring and 6-10 in the inner" (BLACK, 1971, p. 406) which characterise this species. In the figured specimens the arrangement of the holes in the central area appears to be irregular.

Range and Occurrence:

Upper Callovian/Oxfordian? to Tithonian in the western North Atlantic.

Genus Podorhabdus NOEL 1965

Podorhabdus cylindratus NOEL 1965

Pl. 4, Fig. 1; Pl. 7, Fig. 10

- 1965b Podorhabdus cylindratus NOEL, p. 103; Text Fig. 30; Pl. 9, Fig. 3, 7.
- 1976 Podorhabdus cylindratus NOEL 1965 - THIERSTEIN, Pl. 2, Fig. 10, 11.
- 1976 Axopodorhabdus cylindratus (NOEL 1965) - WISE and WIND, p. 279; Pl. 80, Fig. 5, 6; Pl. 81, Fig. 1-4; Pl. 88, Fig. 5, 6.
- 1977 Podorhabdus cylindratus NOEL 1965 - HAMILTON, p. 587; Pl. 1, Fig. 11.
- 1978 Podorhabdus cylindratus NOEL 1965 - HAMILTON, p. 33; Pl. 1, Fig. 10.

Comments:

It seems likely that the Jurassic species, Podorhabdus cylindratus NOEL 1965, is closely related to or synonymous with the Cretaceous form Podorhabdus dietzmanni (REINHARDT 1965) REINHARDT 1967. The author follows the established convention which uses the former name for specimens found in Jurassic deposits.

Range and Occurrence:

Pliensbachian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian/Callovian? to Lower Cretaceous in the western North Atlantic.

Podorhabdus macrogranulatus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Pl. 3, Fig. 13; Pl. 7, Fig. 7

1969 Podorhabdus macrogranulatus PRINS, Pl. 3, Fig. 6; (invalid).

1973 Podorhabdus macrogranulatus PRINS 1969 - ROOD, HAY and BARNARD, p. 377; Pl. 2, Fig. 7.

1977 Podorhabdus macrogranulatus PRINS 1969 ex ROOD, HAY & BARNARD 1973 - HAMILTON, p. 587; Pl. 3, Fig. 3.

Comments:

The light microscope photograph (Pl. 7, Fig. 7) closely resembles the light microscope photograph in BARNARD and HAY (1974, Pl. 5, Fig. 4).

Range and Occurrence:

Lower Toarcian to Middle Bathonian in Portugal.

Podorhabdus rahla NOEL 1965

Pl. 5, Fig. 14

1965b Podorhabdus rahla NOEL, p. 105; Pl. 9, Fig. 8.

1978 Podorhabdus rahla NOEL 1965 - HAMILTON, p. 33; Pl. 1, Fig. 13.

Comments:

The figured specimen clearly illustrates the branches arranged

in a cross around the stem which are characteristic of this species. Podorhabdus rahla is normally rare but it is easily identified under the light microscope if it is present.

Range and Occurrence:

Upper Callovian in Great Britain.

Lower Oxfordian in the western North Atlantic.

Genus Polypodorhabdus NOEL 1965

Polypodorhabdus madingleyensis BLACK 1968

Pl. 4, Fig. 7-9

- 1968 Polypodorhabdus madingleyensis BLACK, p. 806; Pl. 150, Fig. 2.
- 1971 Polypodorhabdus escaigi NOEL 1965 - ROOD, HAY and BARNARD, p. 262; Pl. 3, Fig. 5, 6.
- 1976 Polypodorhabdus escaigi NOEL 1965 - THIERSTEIN, Pl. 2, Fig. 22-25.
- 1976 Polypodorhabdus escaigi NOEL 1965 - WISE and WIND, p. 272; Pl. 77, Fig. 1-3; Pl. 88, Fig. 3, 4.
- 1978 Polypodorhabdus madingleyensis BLACK 1968 - HAMILTON, p. 33; Pl. 1, Fig. 12, 15.

Comments:

Much confusion exists in the literature over the nomenclature concerning this species and a similar form, Polypodorhabdus escaigi NOEL 1965. In their paper, GRÜN and ALLEMANN (1975) clearly stated that specimens in which the lateral bars consist of only one or two elongated elements belong to Polypodorhabdus madingleyensis BLACK 1968. Specimens whose bars are made up of more than two elements belong to Polypodorhabdus escaigi. GRÜN and ALLEMANN also noted that the

distinction between the bars and spaces in Polypodorhabdus madingleyensis is clearer than that in the other species.

Range and Occurrence:

Upper Callovian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Oxfordian to Tithonian in the western North Atlantic.

Genus Retecapsa BLACK 1971 emend. GRÜN & ALLEMANN 1975

Retecapsa angustiforata BLACK 1971

Pl. 4, Fig. 12

- 1968 Cretarhabdus sp. cf. Cretarhabdus crenulatus BRAMLETTE & MARTINI 1964 - GARTNER, (partim), p. 22; Pl. 20, Fig. 10.
- 1969 Cretarhabdus crenulatus crenulatus BRAMLETTE & MARTINI 1964 - BUKRY, p. 35; Pl. 14, Fig. 4-6.
- 1970 Cretarhabdus schizobrachiatus (GARTNER 1968) - REINHARDT, (partim), p. 50; Pl. 1, Fig. 5.
- 1971 Polypodorhabdus schizobrachiatus (GARTNER 1968) - SHAFIK and STRADNER, (partim), p. 87; Pl. 15, Fig. 2.
- 1971 Retecapsa angustiforata BLACK, p. 409; Pl. 33, Fig. 4.
- 1971 Retecapsa levis BLACK, p. 410; Pl. 33, Fig. 1.
- 1971 Retecapsa brightoni BLACK, p. 409; Pl. 33, Fig. 3.
- 1971 Retecapsa neocomiana BLACK, p. 410; Pl. 33, Fig. 2.
- 1971 Cretarhabdus crenulatus BRAMLETTE & MARTINI 1964 - THIERSTEIN, p. 476; Pl. 5, Fig. 10-14.
- 1972 Octopodorhabdus praevisus NOEL 1965 - WILCOXON, p. 432; Pl. 5, Fig. 7.
- 1972 Cretarhabdus octoperforatus FORCHHEIMER, p. 51; Pl. 20, Fig. 1, 2.

- 1972 Cretarhabdus ingens (GORKA 1957) REINHARDT & GORKA 1967 -
HOFFMANN, p. 49; Pl. 10, Fig. 3; Pl. 12, Fig. 3, 4.
- 1976 Retecapsa levis BLACK 1971 - HILL, p. 152; Pl. 5, Fig. 15-19.
- 1976 Retecapsa angustiforata BLACK 1971 - WISE and WIND, p. 305;
Pl. 76, Fig. 6.

Comments:

Only one specimen of the species was recorded in this study.

Range and Occurrence:

Upper Callovian/Oxfordian? in the western North Atlantic.

Retecapsa schizobrachiata (GARTNER 1968) GRÜN & ALLEMANN 1975

Pl. 4, Fig. 10, 11

- 1968 Vekshinella schizobrachiata GARTNER, p. 31; Pl. 13, Fig. 10, 11;
Pl. 20, Fig. 5.
- 1969 Cretarhabdus schizobrachiatus (GARTNER 1968) - BUKRY, p. 36;
Pl. 15, Fig. 4-6.
- 1971 Polypodorhabdus schizobrachiatus (GARTNER 1968) - SHAFIK and
STRADNER, (partim), p. 87; Pl. 15, Fig. 1, 3.
- 1975 Retecapsa schizobrachiata (GARTNER 1968) - GRÜN and ALLEMANN,
p. 175.
- 1976 Cretarhabdus schizobrachiatus (GARTNER 1968) BUKRY 1969 -
BURNS, p. 284; Pl. 3, Fig. 1.
- 1976 Retecapsa tridentata WISE and WIND, p. 306; Pl. 76, Fig. 3-5;
Pl. 88, Fig. 12.
- 1976 Retecapsa sp. WISE and WIND, p. 306; Pl. 78, Fig. 1.

Comments:

The figured specimens clearly illustrate the branching at the

ends of the axial crossbars that is characteristic of this species. This branching is normally clearly visible with a light microscope.

Range and Occurrence:

Oxfordian in Portugal.

Upper Callovian/Oxfordian? in the western North Atlantic.

Genus Staurolithites CARATINI 1963

Staurolithites crux (DEFLANDRE 1954) CARATINI 1963

Pl. 2, Fig. 5; Pl. 7, Fig. 9

- 1954 Discolithus crux DEFLANDRE in DEFLANDRE and FERT, p. 143; Text Fig. 55; Pl. 14, Fig. 4.
- 1957 Discolithus bohotnicae GORKA, p. 273; Pl. 2, Fig. 15.
- 1957 Discolithus mielnicensis GORKA, p. 273; Pl. 2, Fig. 14.
- 1961 Zygolithus crux (DEFLANDRE 1954) - BRAMLETTE and SULLIVAN, p. 149; Pl. 6, Fig. 8-10.
- 1963 Staurolithites crux (DEFLANDRE 1954) - CARATINI, p. 25.
- ?1966 Staurolithites bohotnicae (GORKA 1957) - REINHARDT, p. 33; Pl. 15, Fig. 1; Pl. 19, Fig. 4; Pl. 22, Fig. 8; Pl. 23, Fig. 18.
- 1968 Staurolithites mielnicensis (GORKA 1957) - PERCH-NIELSEN, p. 26; Text Fig. 4; Pl. 2, Fig. 3-5.
- ?1968 Vekshinella ara GARTNER, p. 29; Pl. 2, Fig. 24; Pl. 3, Fig. 15.
- ?1968 Vekshinella imbricata GARTNER, p. 30; Pl. 9, Fig. 16; Pl. 13, Fig. 8.
- ?1970a Zygostephanos crux (DEFLANDRE 1954) - HOFFMANN, p. 166; Text Fig. 3, Fig. 1a-b; Pl. 1, Fig. 1-3; Pl. 4, Fig. 3; Pl. 9, Fig. 5; Pl. 10, Fig. 6.

- 1971 Vekshinella stradneri ROOD, HAY and BARNARD, p. 249; Pl. 1, Fig. 2.
- ?1972 Staurolithites quadriarcullus (NOEL 1965) - WILCOXON, Pl. 3, Fig. 3, 4.
- 1972 Vagalapilla partita FORCHHEIMER, p. 64; Pl. 21, Fig. 1, 2; Pl. 22, Fig. 1-4.
- 1972 Vagalapilla alata FORCHHEIMER, p. 62; Pl. 22, Fig. 5, 6.
- 1976 Vekshinella stradneri ROOD, HAY & BARNARD 1971 - WISE and WIND, (partim), p. 308; Pl. 53, Fig. 5, 6; Pl. 54, Fig. 1-4; Pl. 62, Fig. 1.
- 1976 Vekshinella quadriarculla (NOEL 1965) ROOD, HAY & BARNARD 1971 - WISE and WIND, (partim), Pl. 83, Fig. 4.

Comments:

This species is not common in the studied samples. There is considerable confusion over the nomenclature concerning the species, possibly resulting from the simplified illustrations in the original description (DEFLANDRE 1954). In this study the species can be confused with Staurorhabdus quadriarcullus (NOEL 1965) NOEL 1973, although the presence of a fairly large hole in the centre of the latter species serves to distinguish it from Staurolithites crux which has no central hole.

Range and Occurrence:

Bajocian in Portugal.

Lower Oxfordian in Great Britain.

Oxfordian in the western North Atlantic.

Genus Staurorhabdus NOEL 1973

Staurorhabdus quadriarcullus (NOEL 1965) NOEL 1973

Pl. 2, Fig. 4

- 1965a Discolithus quadriarcullus NOEL, p. 4; Text Fig. 7.
- 1965b Discolithus quadriarcullus NOEL, p. 74; Text Fig. 7; Pl. 1, Fig. 14, 15; Pl. 2, Fig. 1, 2.
- 1971 Vekshinella quadriarculla (NOEL 1965) - ROOD, HAY and BARNARD, p. 250; Pl. 1, Fig. 1.
- 1973 Staurorhabdus quadriarcullus (NOEL 1965) - NOEL, p. 101; Pl. 1, Fig. 5, 6; Pl. 2, Fig. 1-5.
- 1976a Staurorhabdus quadriarcullus (NOEL 1965) NOEL 1973 - KEUPP, p. 371; Text Fig. 6.
- 1976 Vekshinella quadriarculla (NOEL 1965) ROOD, HAY & BARNARD 1971 - WISE and WIND, (partim), p. 307; Pl. 83, Fig. 3; Pl. 84, Fig. 2, 4.
- 1977 Vekshinella quadriarculla (NOEL 1965) ROOD, HAY & BARNARD 1971 - HAMILTON, p. 587; Pl. 3, Fig. 6.
- 1977a Staurorhabdus quadriarcullus (NOEL 1965) NOEL 1973 - KEUPP, p. 48; Pl. 2, Fig. 2; Pl. 15, Fig. 1-6.

Comments:

This is a long ranging but rare species. It is small and delicately constructed. In the complete form it is easily recognised and can be distinguished from Staurolithites crux (DEFLANDRE 1954) CARATINI 1963 by the presence of central hole or hollow central spine.

Range and Occurrence:

Sinemurian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Kimmeridgian in the western North Atlantic.

Genus Stephanolithion DEFLANDRE 1939

Stephanolithion bigoti DEFLANDRE 1939

Pl. 3, Fig. 1, 2; Pl. 8, Fig. 1-4

- 1939 Stephanolithion bigoti DEFLANDRE, p. 1332; Text Fig. 1-14.
- 1968 Stephanolithion sp. LEZAUD, p. 16; Text Fig. 3.
- 1976 Stephanolithion bigoti DEFLANDRE 1939 - MOSHKOVITZ and EHRLICH, p. 9; Pl. 2, Fig. 1-8.
- 1976a Stephanolithion bigoti DEFLANDRE 1939 - KEUPP, p. 372; Text Fig. 18, 19, 22.
- 1976 Stephanolithion bigoti DEFLANDRE 1939 - THIERSTEIN, Pl. 2, Fig. 19.
- 1976 Stephanolithion bigoti DEFLANDRE 1939 - WISE and WIND, p. 272; Pl. 79, Fig. 1-3; Pl. 89, Fig. 1-6.
- 1977a Stephanolithion bigoti DEFLANDRE 1939 - KEUPP, p. 52; Pl. 2, Fig. 3; Pl. 16, Fig. 1; Pl. 17, Fig. 3-6; Pl. 18, Fig. 1-6.
- 1977b Stephanolithion bigoti DEFLANDRE 1939 - KEUPP, p. 105; Pl. 8, Fig. 1.
- 1978 Stephanolithion bigoti DEFLANDRE 1939 - HAMILTON, p. 33; Pl. 1, Fig. 11

Comments:

The long lateral spines and the hexagonal shape of the body of this species makes it easy to identify. Experimentation on specimen preservation has shown that secondary calcite overgrowth may affect the lateral spines of Stephanolithion bigoti as is seen in the sequence of photographs (Pl. 8, Fig. 1-4).

Range and Occurrence:

Callovian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Oxfordian in the western North Atlantic.

Stephanolithion hexum ROOD & BARNARD 1972

Pl. 8, Fig. 7

1972 Stephanolithion hexum ROOD and BARNARD, p. 329; Pl. 1, Fig. 3, 4, 9, 10.

1976 Stephanolithion hexum ROOD & BARNARD 1972 - MOSHKOVITZ and EHRLICH, p. 10; Pl. 2, Fig. 11.

Comments:

This species, with six radial bars in the central area, is smaller and less common in the studied sections than other species of Stephanolithion.

Range and Occurrence:

Bathonian to Callovian in Portugal.

Stephanolithion speciosum DEFLANDRE 1954

Pl. 3, Fig. 3; Pl. 8, Fig. 5

1954 Stephanolithion speciosum DEFLANDRE in DEFLANDRE and FERT, p. 146; Text Fig. 56; Pl. 15, Fig. 7, 8.

1976 Stephanolithion speciosum var. speciosum DEFLANDRE 1954 - MOSHKOVITZ and EHRLICH, p. 10; Pl. 2, Fig. 9, 10.

1976 Stephanolithion speciosum DEFLANDRE 1954 - THIERSTEIN, Pl. 2, Fig. 14.

Comments:

This elliptical species has eight to twelve, stubby lateral spines and eight bars supporting a central spine. ROOD and BARNARD (1972) noted that, in the original description of the species, DEFLANDRE did not give specific details regarding the structure of the central area. However, since the number of lateral spines is variable, the main distinguishing feature of the species is its eight radial bars in the central area.

Range and Occurrence:

Bathonian to Callovian in Portugal.

Stephanolithion speciosum var. octum ROOD & BARNARD 1972

Pl. 3, Fig. 4; Pl. 8, Fig. 6.

1972 Stephanolithion speciosum var. octum ROOD and BARNARD, p. 330;
Pl. 1, Fig. 2, 8.

1974 Stephanolithion speciosum var. octum ROOD & BARNARD 1972 -
BARNARD and HAY, Pl. 3, Fig. 2; Pl. 6, Fig. 1.

Comments:

This variety of Stephanolithion speciosum DEFLANDRE 1954 also has eight radial bars supporting a central spine. In contrast to the species, the variety has eight to twelve long lateral spines. The difference between the length of the spines between the species and the variety is very prominent and might justify raising the variety to species level.

Range and Occurrence:

Bathonian to Callovian in Portugal.

Genus Stradnerlithus BLACK 1971 emend. NOEL 1973

Stradnerlithus asymmetricus (ROOD, HAY & BARNARD 1971) NOEL 1973

1971 Diadozygus asymmetricus ROOD, HAY and BARNARD, p. 255; Pl. 1, Fig. 7.

1973 Stradnerlithus asymmetricus (ROOD, HAY & BARNARD 1971) - NOEL, p. 104; Text Fig. 3D.

1976 Stradnerlithus sp. cf. Stradnerlithus asymmetricus (ROOD, HAY & BARNARD 1971) NOEL 1973 - MOSHKOVITZ and EHRLICH, p. 7; Pl. 1, Fig. 8, 9.

Comments:

This species was very rare in the studied sections.

Range and Occurrence:

Bathonian?/Callovian in Portugal.

Upper Callovian in Great Britain.

Genus Striatomarginis PRINS 1969 ex ROOD, HAY & BARNARD 1973

Striatomarginis primitivus ROOD, HAY & BARNARD 1973

Pl. 2, Fig. 13-15

1973 Striatomarginis primitivus ROOD, HAY and BARNARD, p. 379; Pl. 3, Fig. 4.

1973 Paleopontosphaera veterana PRINS 1969 - ROOD, HAY and BARNARD, (partim), p. 378; Pl. 3, Fig. 3.

1974 Lotharingius sigillatus (STRADNER 1961) - GRÜN, PRINS and ZWEILI, p. 304; Text Fig. 8; Pl. 17, Fig. 3, 4.

Not 1974 Lotharingius primitivus (ROOD, HAY & BARNARD 1973) - GRÜN, PRINS and ZWEILI, p. 305; Text Fig. 9; Pl. 17, Fig. 5, 6.

Comments:

In the original description of this species, ROOD, HAY and BARNARD (1973) noted the presence of a narrow tube cycle (coccolithid rim) and a central area which contained a weakly developed longitudinal bar and four quadrants with four or five diagonal bars in each. The specimen recorded as Paleopontosphaera veterna PRINS 1969 in ROOD, HAY and BARNARD (1973, Pl. 3, Fig. 3) appears, on this definition to be a proximal view of Striatomarginis primitivus.

Similarly, the specimens recorded as Lotharingius sigillatus (STRADNER 1961) in GRÜN, PRINS and ZWEILI (1974, Text Fig. 8; Pl. 17, Fig. 3, 4) should not be placed in the genus Lotharingius NOEL 1973 since members of this genus do not have the type of rim shown here.

Range and Occurrence:

Lower Toarcian to Middle Bathonian in Portugal.

Striatomarginis veterna (PRINS 1969 ex ROOD, HAY & BARNARD 1973)

WISE & WIND 1976

Pl. 2, Fig. 11,12

- 1969 Paleopontosphaera veterna PRINS, p. 554; Pl. 2, Fig. 9; (invalid)
- 1973 Paleopontosphaera veterna PRINS 1969 - ROOD, HAY and BARNARD, (partim), p. 378; Pl. 3, Fig. 2.
- 1974 Lotharingius barozii NOEL 1973 - GRÜN, PRINS and ZWEILI, p. 304; Text Fig. 7; Pl. 17, Fig. 1.
- 1976 Striatomarginis veterna (PRINS 1969 ex ROOD, HAY & BARNARD 1973) - WISE and WIND, p. 306.

Comments:

The author follows WISE and WIND (1976) in placing this species in the genus Striatomarginis PRINS 1969 since it possesses a similar type of rim as that in Striatomarginis primitivus ROOD, HAY & BARNARD 1973.

Range and Occurrence:

Pliensbachian to Lower Bajocian in Portugal.

Genus Tubirhabdus PRINS 1969

Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973

Pl. 2, Fig. 10; Pl. 7, Fig. 1

- 1969 Tubirhabdus patulus PRINS, p. 552; Pl. 1, Fig. 10a-c; (invalid).
1973 Tubirhabdus patulus PRINS 1969 - ROOD, HAY and BARNARD, p. 373;
Pl. 2, Fig. 3.
1977 Tubirhabdus patulus PRINS 1969 ex ROOD, HAY & BARNARD 1973 -
HAMILTON, p. 587; Pl. 4, Fig. 12.

Comments:

This is a small species which is easily recognised by its large central hole.

Range and Occurrence:

Sinemurian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Oxfordian in the western North Atlantic.

Genus Tubodiscus THIERSTEIN 1973 emend. GRÜN & ALLEMANN 1975

Tubodiscus verenae THIERSTEIN 1973 emend. GRÜN & ALLEMANN 1975

Pl. 6, Fig. 9; Pl. 8, Fig. 20

- 1965 Cricolithus pemmatoideus DEFLANDRE in MANIVIT, p. 192; Pl. 2, Fig. 8.
- 1966 Cyclolithus gronosus STOVER, (partim), p. 140; Pl. 1, Fig. 3.
- 1969 Apertapetra gronosa (STOVER 1966) - BUKRY, (partim), p. 26; Pl. 6, Fig. 7-9.
- 1972 Manivitella pemmatoidea (DEFLANDRE in MANIVIT 1965) THIERSTEIN 1971 - ROTH and THIERSTEIN, (partim), Pl. 11, Fig. 10-13.
- 1973 Manivitella gronosa (STOVER 1966) - BLACK, p. 79; Pl. 23, Fig. 4, 5.
- 1973 Manivitella pecten BLACK, p. 79; Pl. 23, Fig. 6-8.
- 1973 Tubodiscus verenae THIERSTEIN, p. 42; Pl. 2, Fig. 1-7.
- 1975 Tubodiscus verenae THIERSTEIN 1973 - GRÜN and ALLEMANN, (emend.), p. 197; Text Fig. 32; Pl. 10, Fig. 1-12.
- 1976 Tubodiscus verenae THIERSTEIN 1973 emend. GRÜN & ALLEMANN 1975 - THIERSTEIN, Pl. 3, Fig. 11-14.
- 1976 Tubodiscus sp. cf. Tubodiscus verenae THIERSTEIN 1973 emend. GRÜN & ALLEMANN 1975 - WISE and WIND, p. 307; Pl. 67, Fig. 5, 6.

Comments:

In the light microscope this species might be confused with Manivitella pemmatoidea (DEFLANDRE in MANIVIT 1965) THIERSTEIN 1971. In the original description of Tubodiscus verenae, THIERSTEIN (1973) suggested that species can be distinguished from Manivitella pemmatoidea by focusing at different levels to reveal the central tube and shields and by the fact that the central tube appears as a bright ring. (Manivitella pemmatoidea does not have this central tube.) The

differentiation was further clarified by GRÜN and ALLEMANN (1975) who restricted the forms with only two cycles of elements to the genus Manivitella while placing those with three cycles of elements in the genus Tubodiscus.

Range and Occurrence:

Upper Callovian?/Oxfordian to Lower Cretaceous in the western North Atlantic.

Genus Watznaueria REINHARDT 1964

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968

Pl. 1, Fig. 5, 6, 13

- 1959 Tremalithus barnesae BLACK in BLACK and BARNES, p. 325; Pl. 9, Fig. 1, 2.
- 1964 Colvillea barnesae (BLACK 1959) - BLACK, p. 311.
- 1964 Coccolithus sp. cf. Coccolithus barnesae (BLACK 1959) - BRAMLETTE and MARTINI, p. 298; Pl. 1, Fig. 13, 14.
- 1964 Tergestiella barnesae (BLACK 1959) - REINHARDT, p. 753.
- 1964 Watznaueria angustoralis REINHARDT, p. 753; Text Fig. 4; Pl. 2, Fig. 2.
- 1965b Ellipsagelosphaera frequens NOEL, (partim), p. 119; Pl. 16, Fig. 1-4; Pl. 19, Fig. 4.
- 1966 Maslovella barnesae (BLACK 1959) - TAPPAN and LOEBLICH, p. 43.
- 1966 Coccolithus penepelagicus STOVER, (partim), p. 139; Pl. 1, Fig. 10; Pl. 3, Fig. 22B; Pl. 8, Fig. 5.
- 1968 Coccolithus barnesae (BLACK 1959) - STRADNER, ADAMIKER and MARESCH, (partim), p. 24; Text Fig. 8; Pl. 1; Pl. 2, Fig. 2-5.
- 1968 Watznaueria barnesae (BLACK 1959) - PERCH-NIELSEN, (partim), p. 69; Text Fig. 32; Pl. 22, Fig. 1-7.

- 1968 Coccolithus hoellivikensis FORCHHEIMER (partim), p. 28; SEM 6, 7, 8, 9.
- 1970 Watznaueria sp. aff. Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - NOEL, (partim), p. 92; Pl. 35, Fig. 2-4, 6, 8, 10, 11.
- 1976 Watznaueria sp. MOSHKOVITZ and EHRLICH, (partim), p. 13; Pl. 6, Fig. 1-5.
- 1976a Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - KEUPP, p. 373; Text Fig. 1.
- 1976b Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - KEUPP, Pl. 1, Fig. b; Pl. 3, Fig. a, b, d.
- 1976 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - HILL, p. 159; Pl. 12, Fig. 16-18; Pl. 15, Fig. 21-24.
- 1976 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - WISE and WIND, p. 272; Pl. 68, Fig. 3, 4; Pl. 88, Fig. 11.
- 1977a Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - KEUPP, p. 38; Pl. 12, Fig. 1-3, 5, 6 (?Fig. 4).
- 1977 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - VERBEEK, p. 85; Pl. 4, Fig. 6.
- 1978 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - HAMILTON, p. 33; Pl. 1, Fig. 3.

Comments:

Members of the genus Watznaueria have a construction similar to that in members of the genus Ellipsagelosphaera NOEL 1965, except that they lack a central tube of elements.

Specimens of Watznaueria barnesae can be quite large. It seems likely that dissolution of specimens of this species may result in the formation of the form known as Calolithus martelae NOEL 1965.

Range and Occurrence:

Lower Bajocian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian/Callovian? to Lower Cretaceous in the western North Atlantic.

Watznaueria biporta BUKRY 1969

Pl. 1, Fig. 7-9

- 1965 Coccolithus sp. BLACK, p. 133; Text Fig. 12.
- 1965b Ellipsagelosphaera frequens NOEL, (partim), p. 119; Pl. 13, Fig. 1-3.
- 1968 Watznaueria barnesae (BLACK 1959) - PERCH-NIELSEN, (partim), p. 69; Pl. 23, Fig. 16.
- 1969 Watznaueria biporta BUKRY, p. 32; Pl. 10, Fig. 8-10.
- 1970 Coccolithus bornholmensis FORCHHEIMER, (partim), p. 12; Text Fig. 5-7, 12.
- 1971 Watznaueria cynthae WORSLEY, p. 1314; Pl. 2, Fig. 23-25.
- 1971 Watznaueria communis REINHARDT 1964 - ROOD, HAY and BARNARD, (partim), p. 268; Pl. 5, Fig. 3, 4.
- 1972 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - LAUER in GRÜN et al., (partim), p. 154; Pl. 26, Fig. 3, 4.
- 1972 Calolithus martelae NOEL 1965 - WILCOXON, p. 431; Pl. 3, Fig. 7.
- 1973 Margolatus bornholmensis (FORCHHEIMER 1970) - BLACK, p. 81; Pl. 24, Fig. 6, 11, 12.
- 1973 Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968 - PRIEWALDER, p. 27; Pl. 14, Fig. 6.
- 1976 Watznaueria biporta BUKRY 1969 - BURNS, p. 298; Pl. 5, Fig. 9, 10.
- 1977 Watznaueria biporta BUKRY 1969 - VERBEEK, p. 85; Pl. 4, Fig. 5.

1978 Watznaueria biporta BUKRY 1969 - HAMILTON, p. 33; Pl. 1, Fig. 6.

Comments:

This species is generally smaller and less common than Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968. It has two small holes in the central area as opposed to the narrow slit in Watznaueria barnesae.

Range and Occurrence:

Bathonian to Oxfordian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian/Callovian? to Lower Cretaceous in the western North Atlantic.

Genus Zygodiscus BRAMLETTE & SULLIVAN 1961 emend. GARTNER 1968

Zygodiscus elegans GARTNER 1968

Pl. 2, Fig. 2

1968 Zygodiscus elegans GARTNER, p. 32; Pl. 10, Fig. 3-6; Pl. 12, Fig. 3a-c, 4a-c; Pl. 27, Fig. 1.

1971 Zygodiscus acanthus (REINHARDT 1965) REINHARDT 1966 - MANIVIT, p. 77; Pl. 13, Fig. 8-11.

1972 Glaukolithus elegans (GARTNER 1968) - ROTH and THIERSTEIN, p. 437; Pl. 10, Fig. 16-20.

1976 Zygodiscus elegans GARTNER 1968 - HILL, p. 162; Pl. 12, Fig. 23, 24; Pl. 15, Fig. 27, 28.

1977 Zygodiscus elegans GARTNER 1968 - VERBEEK, p. 97; Pl. 7, Fig. 10.

Comments:

This species is similar to Zygodiscus noeli (ROOD, HAY & BARNARD 1971) n. comb. but the figured specimens of these two species (Pl. 2, Fig. 2 and

Pl. 2, Fig. 3) clearly show that they can be distinguished on the presence or absence of an axial canal in the stem. In Zygodiscus elegans there is no axial canal.

Range and Occurrence:

Callovian? to Lower Cretaceous in the western North Atlantic.

Zygodiscus erectus (DEFLANDRE 1954) MANIVIT 1971

Pl. 2, Fig. 1

- 1954 Zygodiscus erectus DEFLANDRE in DEFLANDRE and FERT, (partim), p. 150; Text Fig. 60, 61; Pl. 15, Fig. 14-17.
- 1965 Zeugrhabdotus erectus (DEFLANDRE 1954) - REINHARDT, p. 37.
- 1971 Zygodiscus erectus (DEFLANDRE 1954) - MANIVIT, p. 78; Pl. 29, Fig. 1-3.
- 1976 Zeugrhabdotus noeli ROOD, HAY & BARNARD 1971 - WISE and WIND, (partim), p. 308; Pl. 82, Fig. 1-4, 6; Pl. 89, Fig. 12.
- 1976 Zeugrhabdotus erectus (DEFLANDRE 1954) REINHARDT 1965 - WISE and WIND, p. 308; Pl. 81, Fig. 6; Pl. 83, Fig. 2.
- 1977a Zeugrhabdotus salillum (NOEL 1965) ROOD, HAY & BARNARD 1971 - KEUPP, (partim), p. 50; Pl. 16, Fig. 2-5.

Comments:

In their remarks on this species, ROOD, HAY and BARNARD (1971, p. 252) described how the two openings are spanned by a delicate, perforate sheet which can only be detected with an electron microscope. No specimens showing this structure were found in this study. However, the species can be easily identified by its narrow rim and narrow crossbar.

Zygodiscus erectus shows some variation in size. In the Lower Jurassic it is usually very small and rare in its occurrence. It increases

in size during the Callovian and Oxfordian when it becomes quite large, more robust and more common.

Range and Occurrence:

Sinemurian to Lower Kimmeridgian in Portugal.

Upper Callovian to Lower Oxfordian in Great Britain.

Callovian? to Lower Cretaceous in the western North Atlantic.

Zygodiscus noeli (ROOD, HAY & BARNARD 1971) n. comb.

Pl. 2, Fig. 3

- 1954 Zygodiscus erectus DEFLANDRE in DEFLANDRE and FERT, (partim), p. 150; Text Fig. 62.
- 1965b Zygodiscus erectus DEFLANDRE 1954 - NOEL, p. 62; Text Fig. 2; Pl. 1, Fig. 3, 4.
- 1968 Zygodiscus erectus DEFLANDRE 1954 - STRADNER, ADAMIKER and MARESCH, (partim), p. 34; Pl. 25; Pl. 26, Fig. 1, 2.
- 1971 Zeugrhabdotus noeli ROOD, HAY and BARNARD, p. 252; Pl. 1, Fig. 4.
- 1976 Zeugrhabdotus noeli ROOD, HAY & BARNARD 1971 - MOSHKOVITZ and EHRLICH, p. 6; Pl. 1, Fig. 1-4.
- 1976 Zeugrhabdotus noeli ROOD, HAY & BARNARD 1971 - WISE and WIND, (partim), p. 308; Pl. 82, Fig. 1; Pl. 83, Fig. 1.
- 1977a Zeugrhabdotus noeli ROOD, HAY & BARNARD 1971 - KEUPP, p. 50; Pl. 17, Fig. 1, 2.

Comments:

This species is similar to Zygodiscus elegans GARTNER 1968 but may be recognised by the presence of a large axial canal in the stem, as is clearly illustrated in Pl. 2, Fig. 3.

Range and Occurrence:

Bajocian to Oxfordian in Portugal.

Callovian? to Lower Cretaceous in the western North Atlantic.

13.3. Incertae sedis

Genus Conusphaera TREJO 1969

Conusphaera mexicana TREJO 1969

Pl. 7, Fig. 21

1965b "Particule calcaire" NOEL, Pl. 28, Fig. 4, 7, 9.

1969 Conusphaera mexicana TREJO, p. 6; Text Fig. 1-4; Pl. 1, Fig. 1-7;
Pl. 2, Fig. 1-8; Pl. 3, Fig. 1-6; Pl. 4, Fig. 1-6.

1976 Conusphaera mexicana TREJO 1969 - THIERSTEIN, Pl. 2, Fig. 26, 27.

Comments:

"
GRUN and ALLEMANN (1975, p. 195) include the species Cretarturbella rothii THIERSTEIN 1971 in their list of synonyms. It is difficult to distinguish the three cycles of elements described by GRUN and ALLEMANN in the figured specimens of Cretarturbella rothii, but the structure seen in THIERSTEIN's paratype (1971, Pl. 3, Fig. 1) and the overall rectangular shape of the specimens are thought to be sufficiently distinct to warrant two separate species.

Range and Occurrence:

Tithonian to Lower Cretaceous in the western North Atlantic.

Genus Micrantholithus DEFLANDRE 1950

Micrantholithus hoschulzi (REINHARDT 1966) THIERSTEIN 1971

Pl. 8, Fig. 14, 15

- 1966 Braarudosphaera hoschulzi REINHARDT, p. 42; Pl. 21, Fig. 3.
1971 Micrantholithus hoschulzi (REINHARDT 1966) - THIERSTEIN, p. 482;
Pl. 1, Fig. 12-15.
1975 Micrantholithus crenulatus BRAMLETTE & SULLIVAN 1961 - GRÜN and
ALLEMANN, p. 192; Pl. 8, Fig. 3-5.

Comments:

In their synonym list for Micrantholithus crenulatus BRAMLETTE & SULLIVAN 1961, GRÜN and ALLEMANN included many forms which previous authors had described as separate species on the grounds that they are all variants of the single species which have been differentially affected by dissolution and secondary calcate overgrowth. In this study Micrantholithus hoschulzi is recognised as a separate species.

Range and Occurrence:

Lower Cretaceous in the western North Atlantic.

Genus Nannoconus KAMPTNER 1931

Nannoconus steinmanni KAMPTNER 1931

Pl. 6, Fig. 7, 8; Pl. 8, Fig. 23, 24

- 1925a "Embryon de Lagena" DE LAPPARENT, p. 104; Text Fig. F1.
1925b "Embryon de Lagena" DE LAPPARENT, Pl. 10, Fig. F1.
1931 Lagena colomi DE LAPPARENT, p. 222.
1931 Nannoconus steinmanni KAMPTNER, p. 289; Text Fig. 1-3.

- 1938 ?Nannoconus colomi (DE LAPPARENT 1931) - KAMPTNER, p. 250:
Text Fig. 1.
- 1948 Nannoconus colomi (DE LAPPARENT 1931) KAMPTNER 1938 - COLOM,
(partim), p. 252; Text Fig. 7.
- 1962 Nannoconus steinmanni KAMPTNER 1931 - BALDI-BEKE, p. 155; Pl. 1,
Fig. 1-4; Pl. 2, Fig. 1-6.
- 1972 Nannoconus steinmanni KAMPTNER 1931 - DERES and ACHERITEGUY,
Pl. 1, Fig. 2, 8.
- 1976 Nannoconus colomi (DE LAPPARENT 1931) KAMPTNER 1938 - THIERSTEIN,
Pl. 2, Fig. 28.

Comments:

There is considerable confusion in the literature regarding the nomenclature of this species and the similar form Nannoconus colomi (DE LAPPARENT 1931) KAMPTNER 1938. Many authors have regarded Nannoconus steinmanni as a junior synonym of Nannoconus colomi. BALDI-BEKE (1962) clearly showed that Nannoconus steinmanni has a uniformly narrow central canal which extends throughout its length, while Nannoconus colomi, although similar in outline, has a narrow canal which grows wider at the base to give a bulbous cavity. The author therefore regards Nannoconus steinmanni as a separate species. Nannoconus colomi was not recorded in this study.

Range and Occurrence:

Tithonian? to Lower Cretaceous in the western North Atlantic.

Nannoconus truitti BRONNIMANN 1955

Pl. 6, Fig. 15; Pl. 8, Fig. 21, 22

- 1955 Nannoconus truitti BRONNIMANN, p. 38; Text Fig. 2f-j; Pl. 2,
Fig. 2-5, 7.

- 1960 Nannoconus colomi (DE LAPPARENT 1931) KAMPTNER 1938 - CARATINI,
p. 106; Text Fig. 2, 4, 5.
- 1976 Nannoconus truitti BRONNIMANN 1955 - HILL, p. 164; Pl. 9, Fig. 10-15; Pl. 14, Fig. 23-26.
- 1976 Nannoconus truitti BRONNIMANN 1955 - WISE and WIND, p. 272;
Pl. 72, Fig. 1-5; Pl. 73, Fig. 1, 2.
- 1977 Nannoconus truitti BRONNIMANN 1955 - VERBEEK, p. 120; Pl. 12,
Fig. 3, 4?

Comments:

This species has a diameter nearly equal to its length and therefore appears to be square in longitudinal section. In this view it can be readily distinguished from Nannoconus steinmanni KAMPTNER 1931 which has an elongated longitudinal section.

Range and Occurrence:

Tithonian? to Lower Cretaceous in the western North Atlantic.

Genus Schizosphaerella DEFLANDRE & DANGEARD 1938

Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938

Pl. 5, Fig. 1, 2; Pl. 7, Fig. 5

- 1938 Schizosphaerella punctulata DEFLANDRE and DANGEARD, p. 1115;
Fig. 1-6.
- 1961 Nannopatina grandaeva STRADNER, p. 78; Text Fig. 1-7.
- 1976 Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938 - THIERSTEIN,
Pl. 2, Fig. 3.
- 1977 Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938 - HAMILTON,
p. 587; Pl. 1, Fig. 1-3; Pl. 3, Fig. 1, 2.

Comments:

The original description of this species (DEFLANDRE and DANGEARD 1938) gave good illustrations of this globular calcareous body which is made of two dissimilar valves. Commonly, these valves are separated and free. Pl. 5, Fig. 2 is a side view of the deeper of the two valves, the hypovalve, and it clearly shows the nature of the ornamentation. Pl. 5, Fig. 1 is an equatorial view of the hypovalve showing the circular groove in which the epivalve is embedded.

Range and Occurrence:

Sinemurian to Lower Kimmeridgian in Portugal.

Rhaetian to Hettangian and Upper Callovian to Lower Oxfordian in Great Britain.

Bathonian? to Lower Kimmeridgian in the western North Atlantic.

Genus Tetralithus GARDET 1955

Tetralithus gothicus DEFLANDRE 1959

Pl. 6, Fig. 1; Pl. 8, Fig. 13

- 1959 Tetralithus gothicus DEFLANDRE, p. 138; Pl. 3, Fig. 25.
- 1961 Tetralithus pyramidus GARDET 1955 - STRADNER, p. 83; Text Fig. 90,91.
- 1968 Tetralithus? LEZAUD, p. 17; Text Fig. 20.
- 1976 Tetralithus gothicus DEFLANDRE 1959 - THIERSTEIN, Pl. 5, Fig. 24, 25.
- 1976 Tetralithus gothicus DEFLANDRE 1959 - WISE and WIND, p. 272; Pl. 50, Fig. 3.
- 1977 Quadrum gothicum (DEFLANDRE 1959) PRINS & PERCH-NIELSEN in MANIVIT et al. 1977 - VERBEEK, p. 122; Pl. 12, Fig. 10.

Comments:

This species is mainly recorded in Upper Cretaceous sediments, but specimens which closely resemble the original figure and other illustrations have been recorded in many of the samples studied here.

Range and Occurrence:

Bathonian to Lower Kimmeridgian in Portugal.

Bathonian? to Lower Cretaceous in the western North Atlantic.

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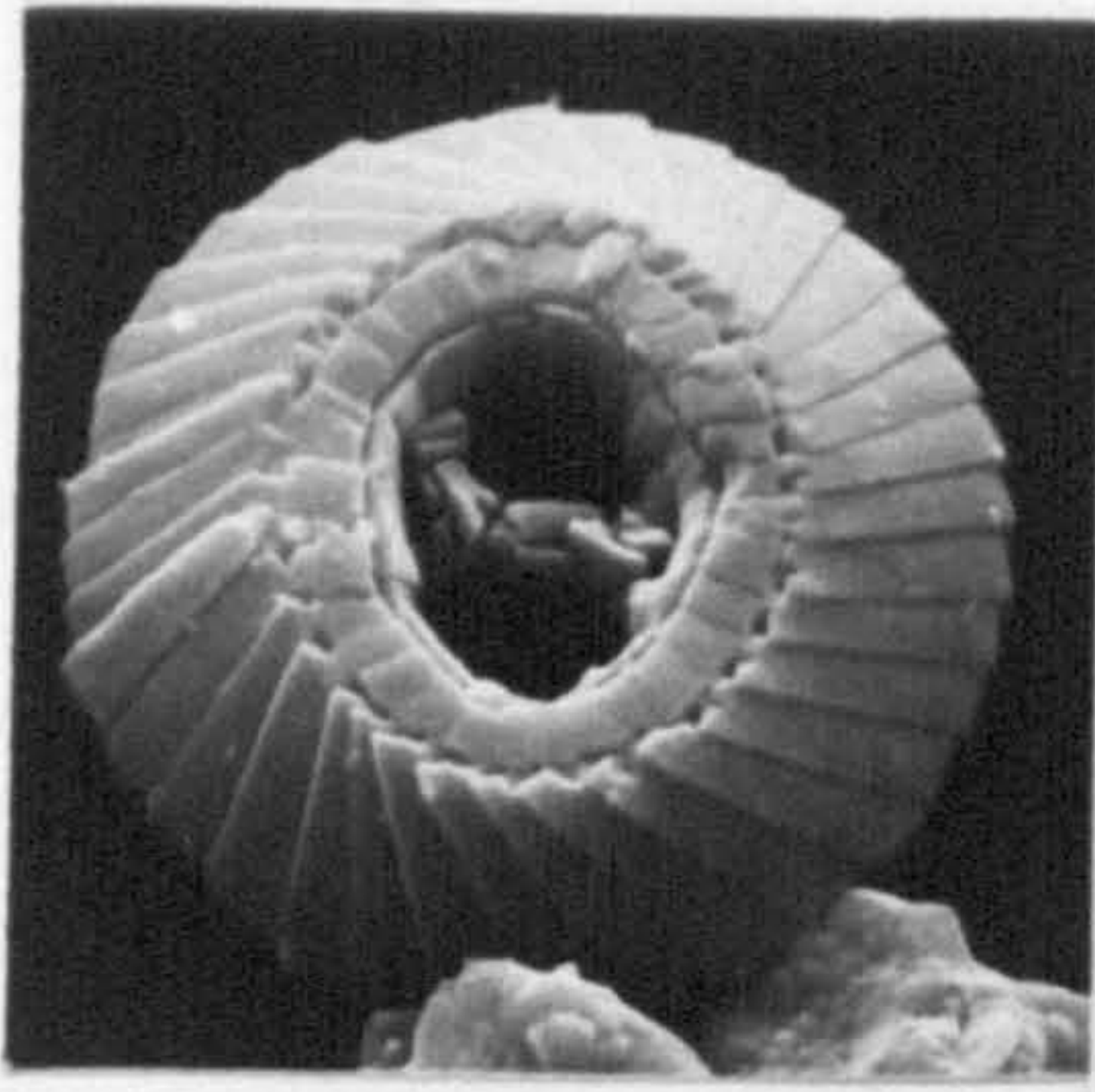
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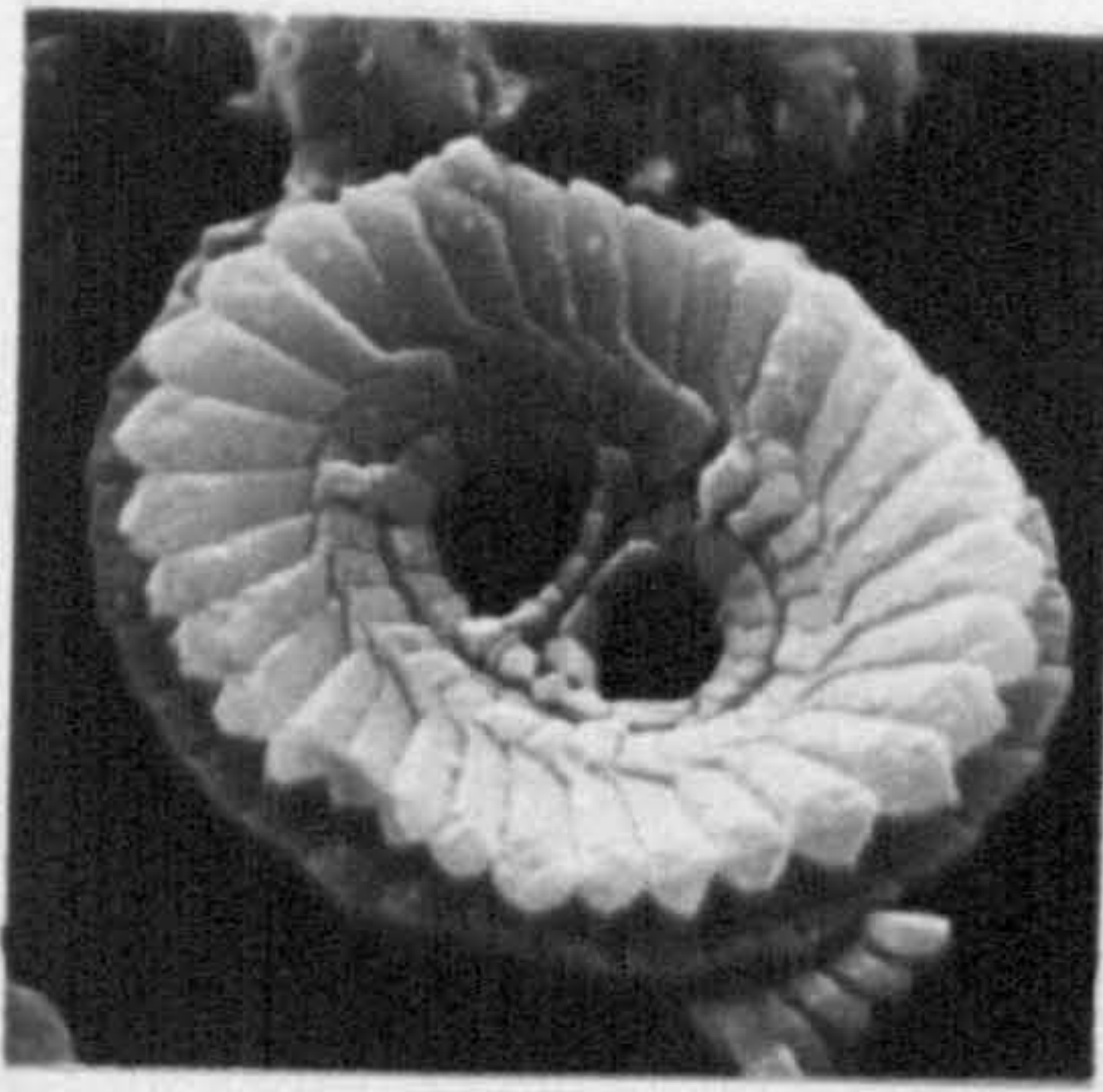
PLATE 1

- Fig. 1 Ellipsagelosphaera britannica (STRADNER), Distal view,
x 3,800, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-515-20.
- Fig. 2 Ellipsagelosphaera britannica (STRADNER), Proximal view,
x 4,700, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-515-16.
- Fig. 3 Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN, Distal side,
x 5,500, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-33.
- Fig. 4 Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN, Proximal side,
x 6,000, Lower Oxfordian, Skye, Neg. no. UCL-464-3.
- Fig. 5 Watznaueria barnesae (BLACK), Distal side,
x 2,200, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-16.
- Fig. 6 Watznaueria barnesae (BLACK), Distal side,
x 5,600, Callovian, D.S.D.P. Site 105, Neg. no. UCL-515-5.
- Fig. 7 Watznaueria biporta BUKRY, Distal side,
x 3,400, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL- 590-3.
- Fig. 8 Watznaueria biporta BUKRY, Proximal side
x 7,200, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-10.
- Fig. 9 Watznaueria biporta BUKRY, Distal side,
x 3,400, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-600-15.
- Fig. 10 Cyclagelosphaera margereli NOEL, Distal side
x 7,900, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-20.
- Fig. 11 Coccosphere of Cyclagelosphaera margereli NOEL,
x 3,900, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-22.
- Fig. 12 Coccosphere of Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN
x 2,600, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-588-2.
- Fig. 13 Coccosphere of Watznaueria barnesae (BLACK)
x 2,700, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-590-14.
- Fig. 14 Coccosphere of Biscutum ellipticum (GORKA)
x 3,000, Bathonian, Cap Mondego, Neg. no. UCL-604-3.
- Fig. 15 Coccosphere of Ellipsagelosphaera sp.
x 2,400, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-654-27.

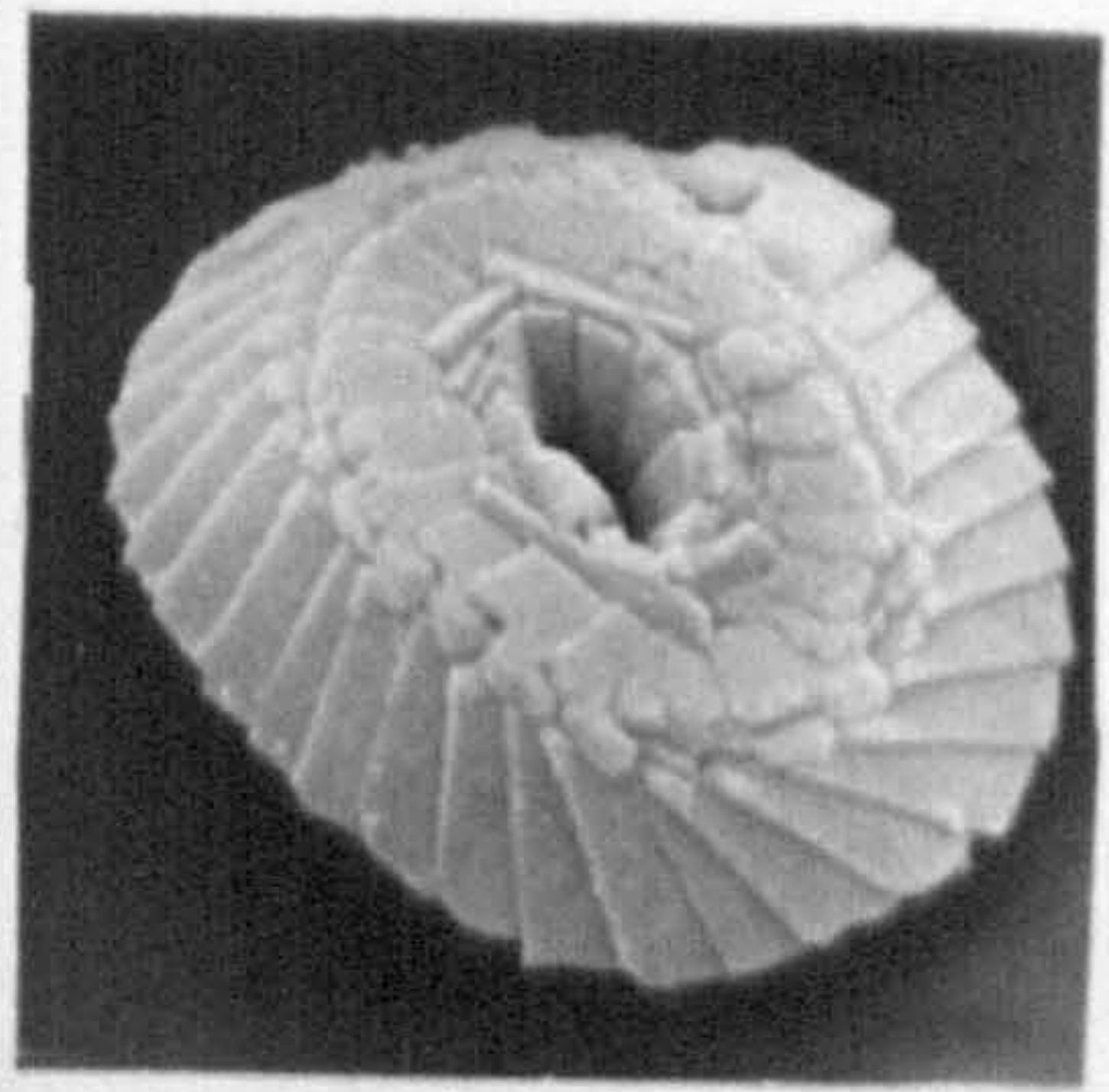
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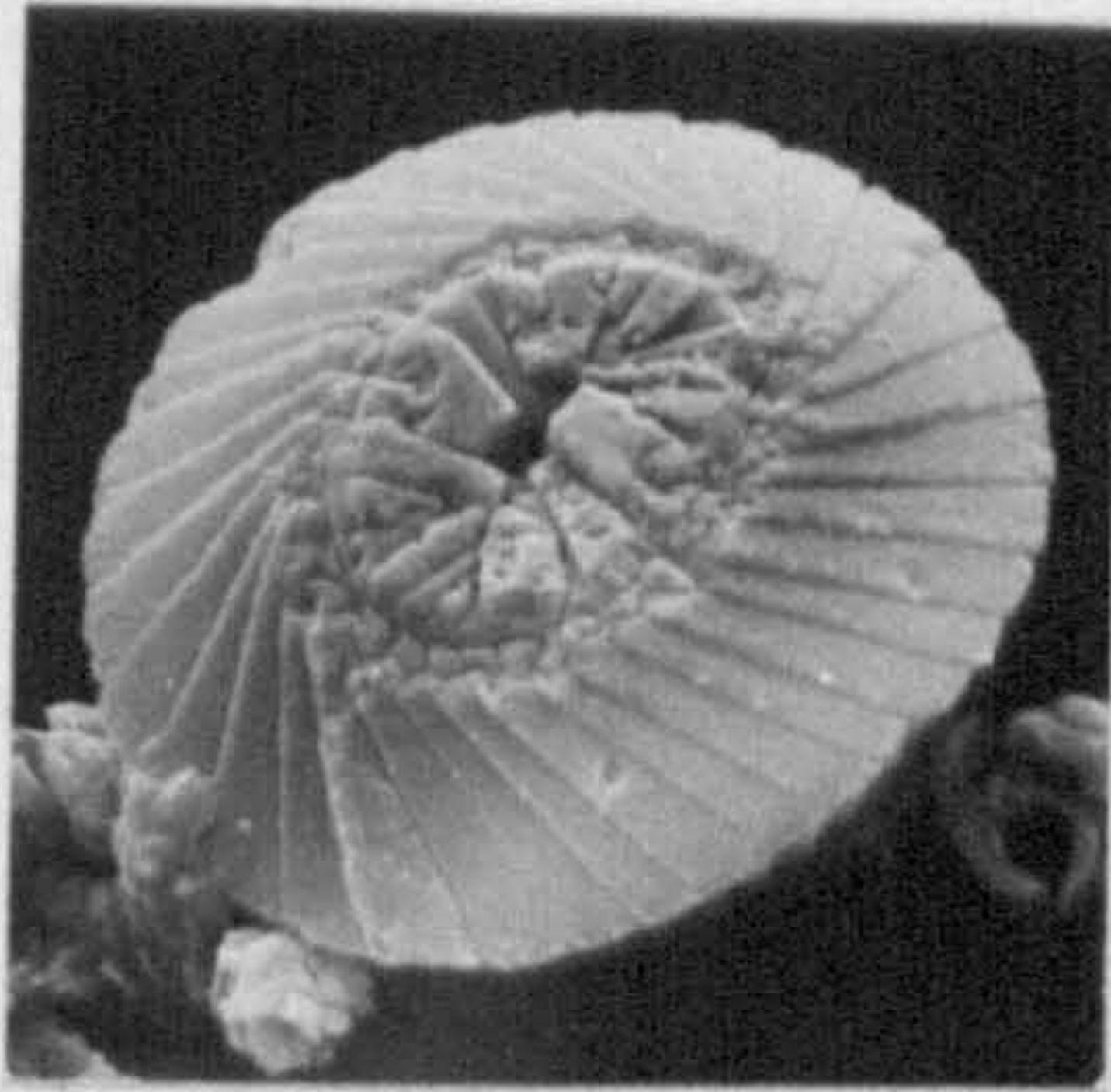
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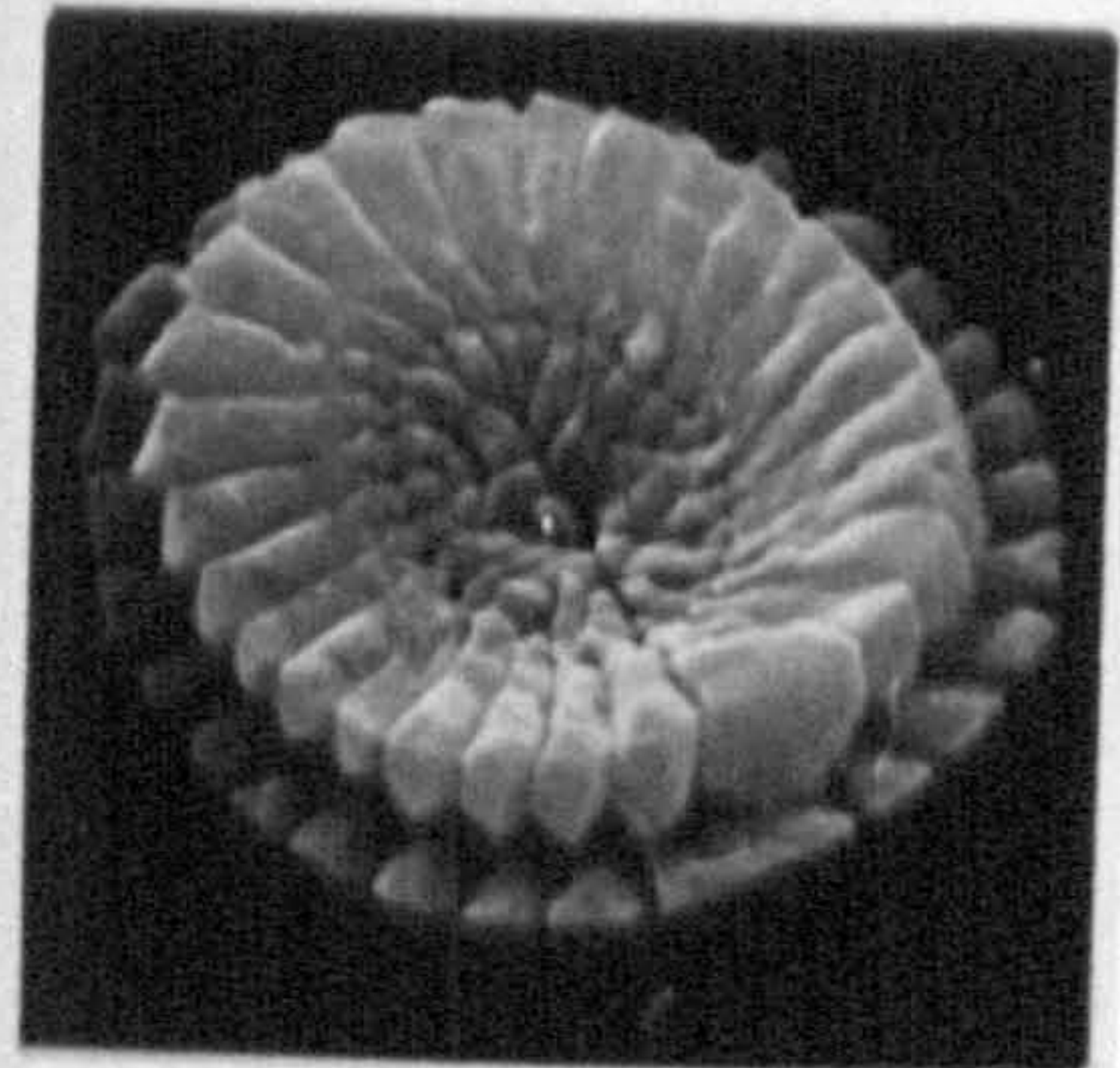
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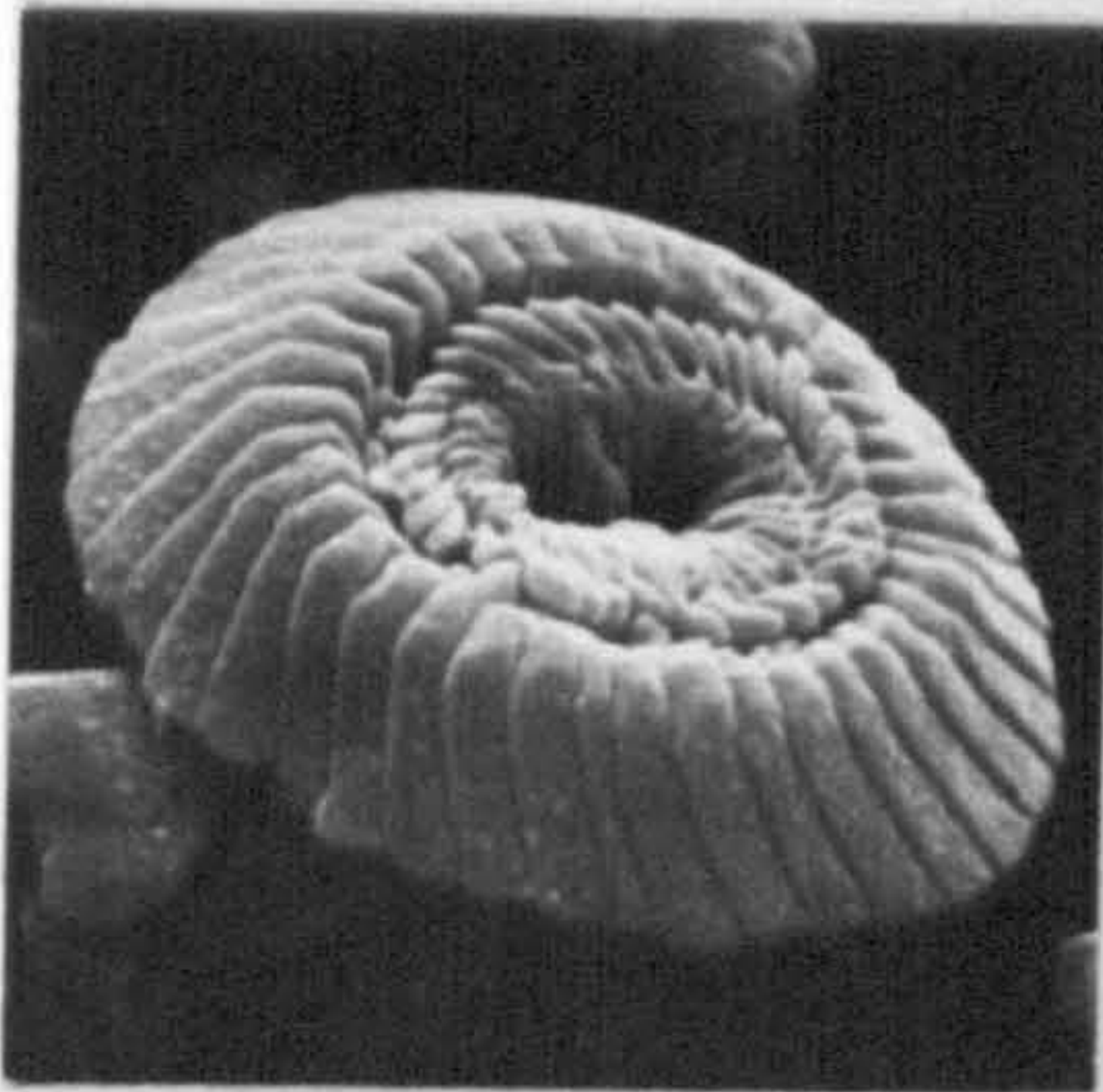
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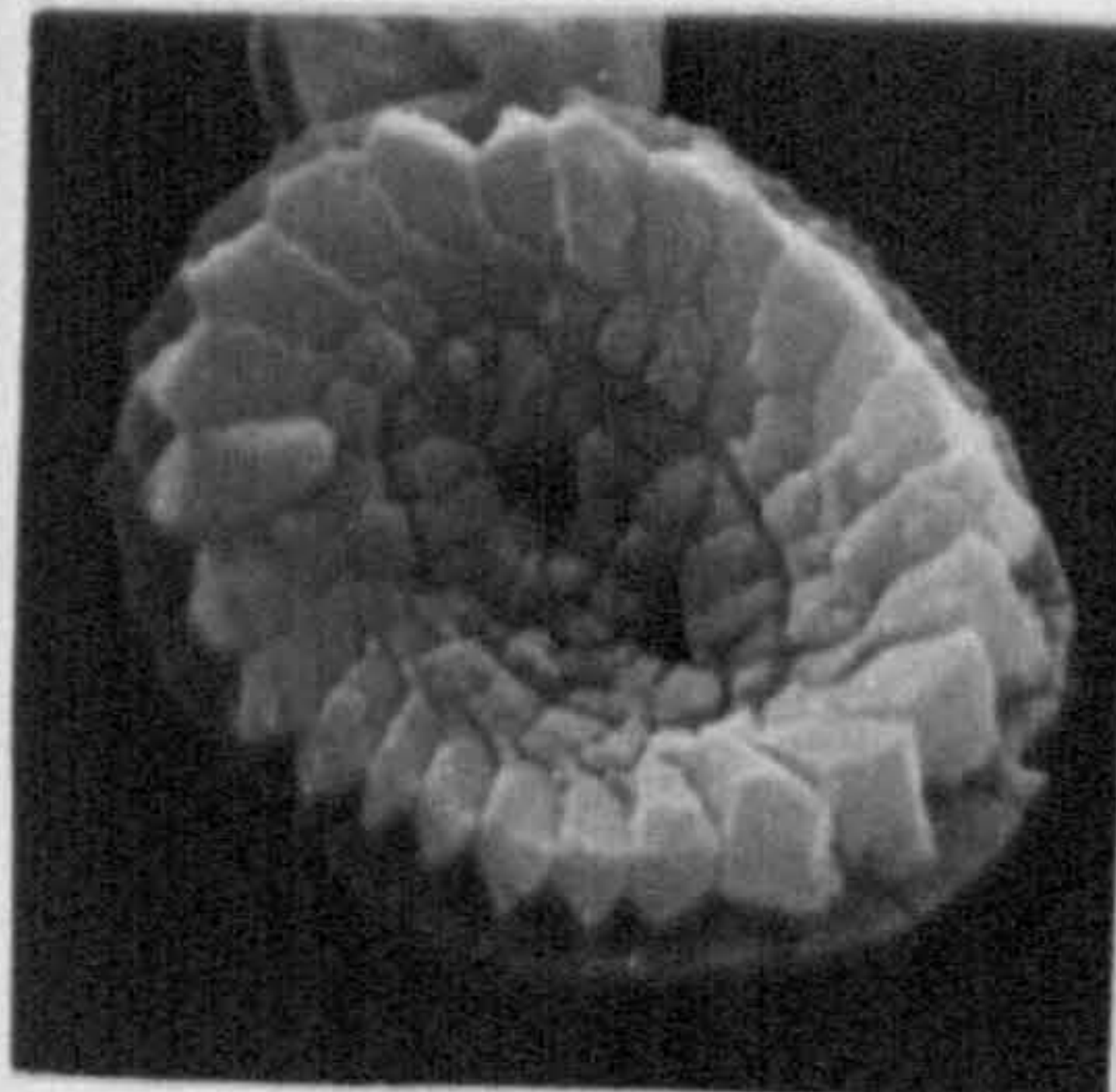
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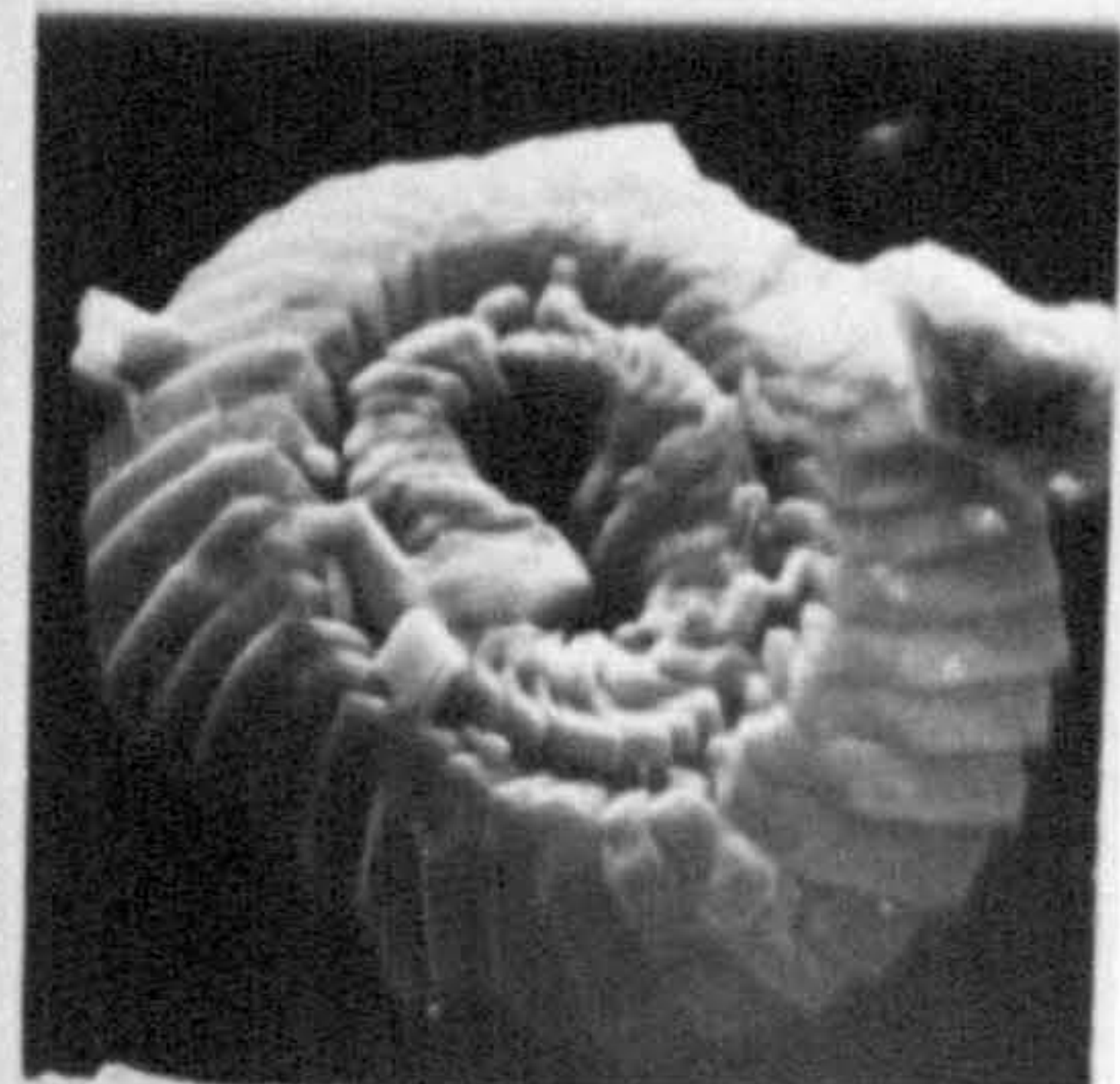
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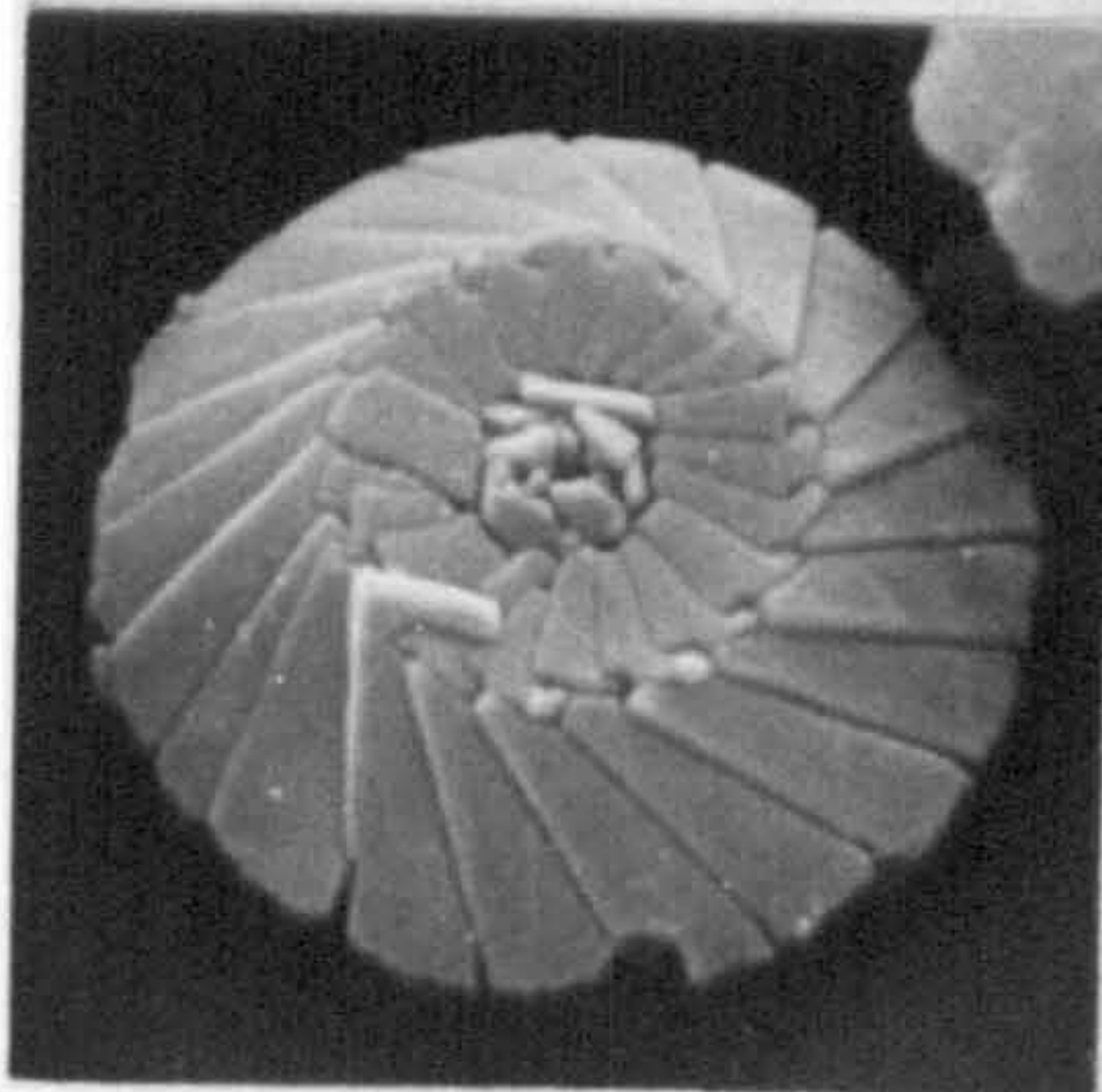
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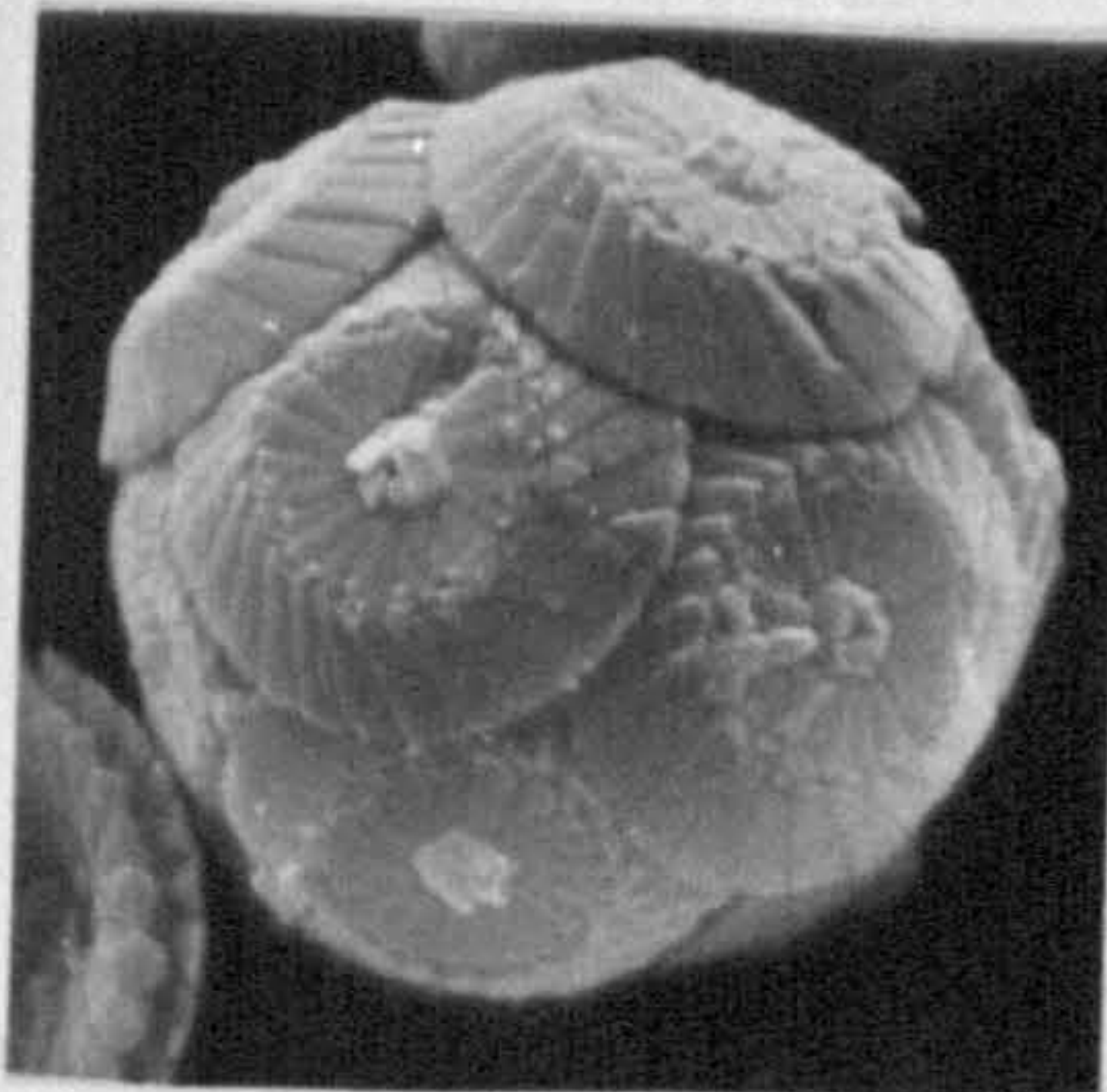
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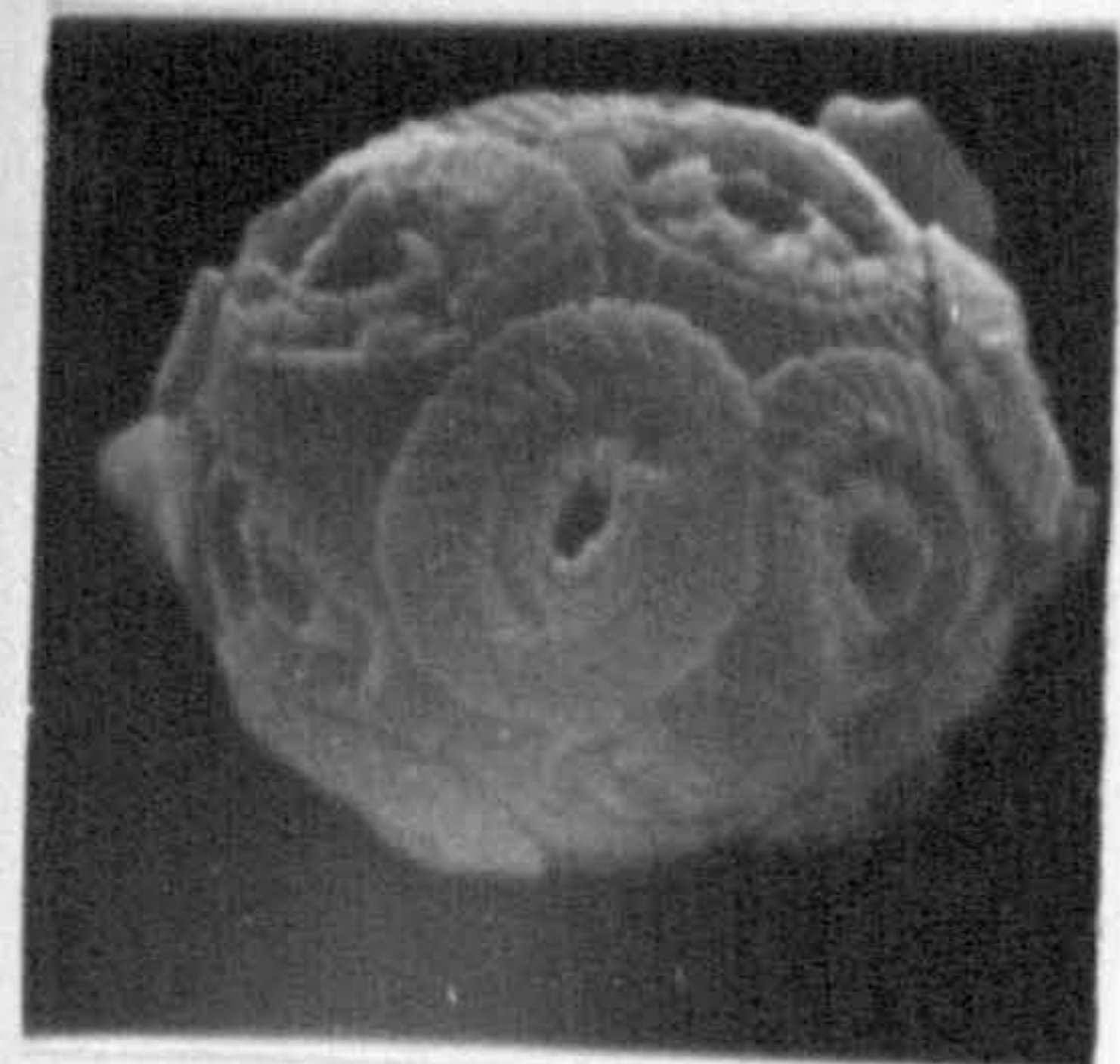
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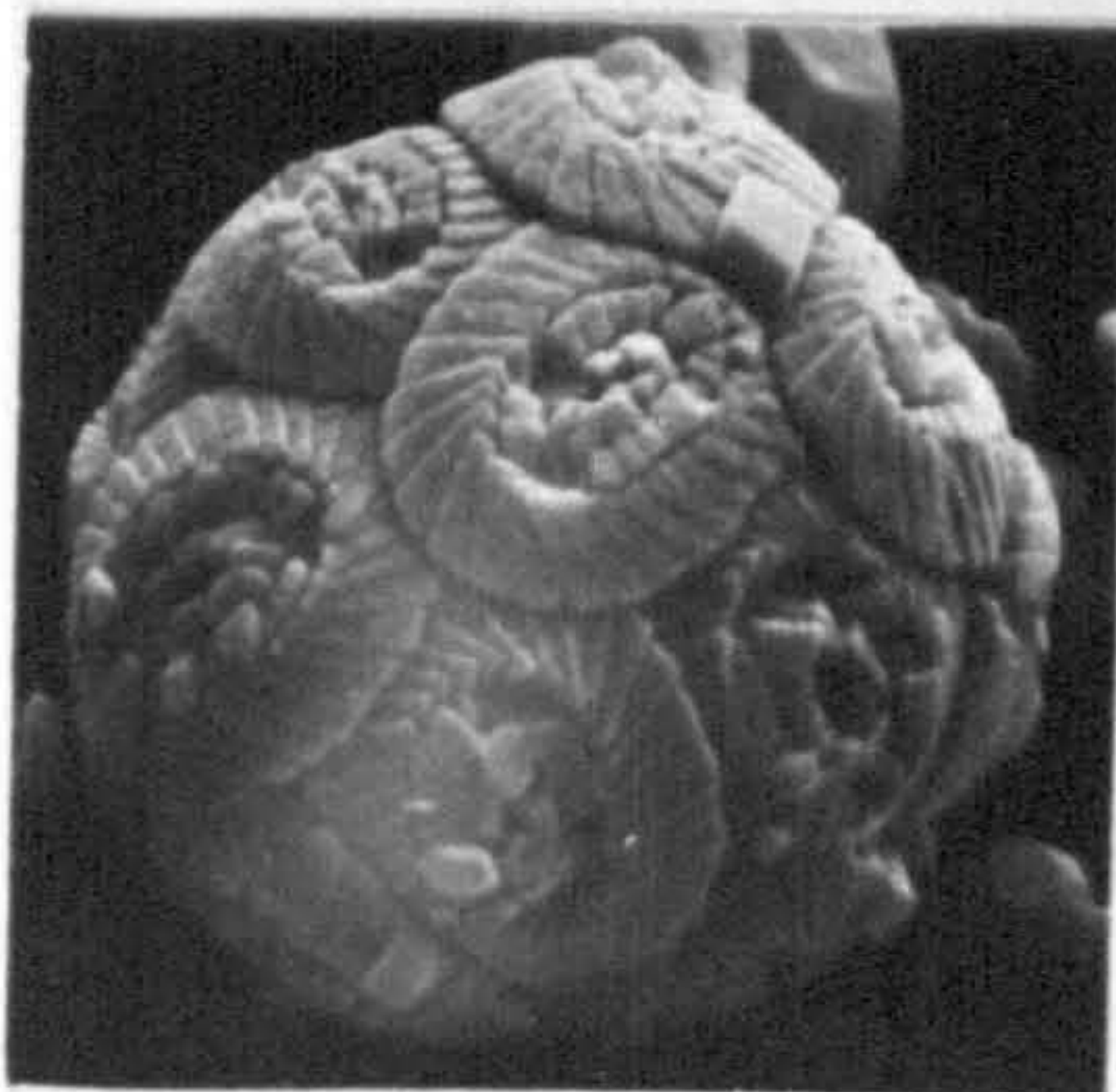
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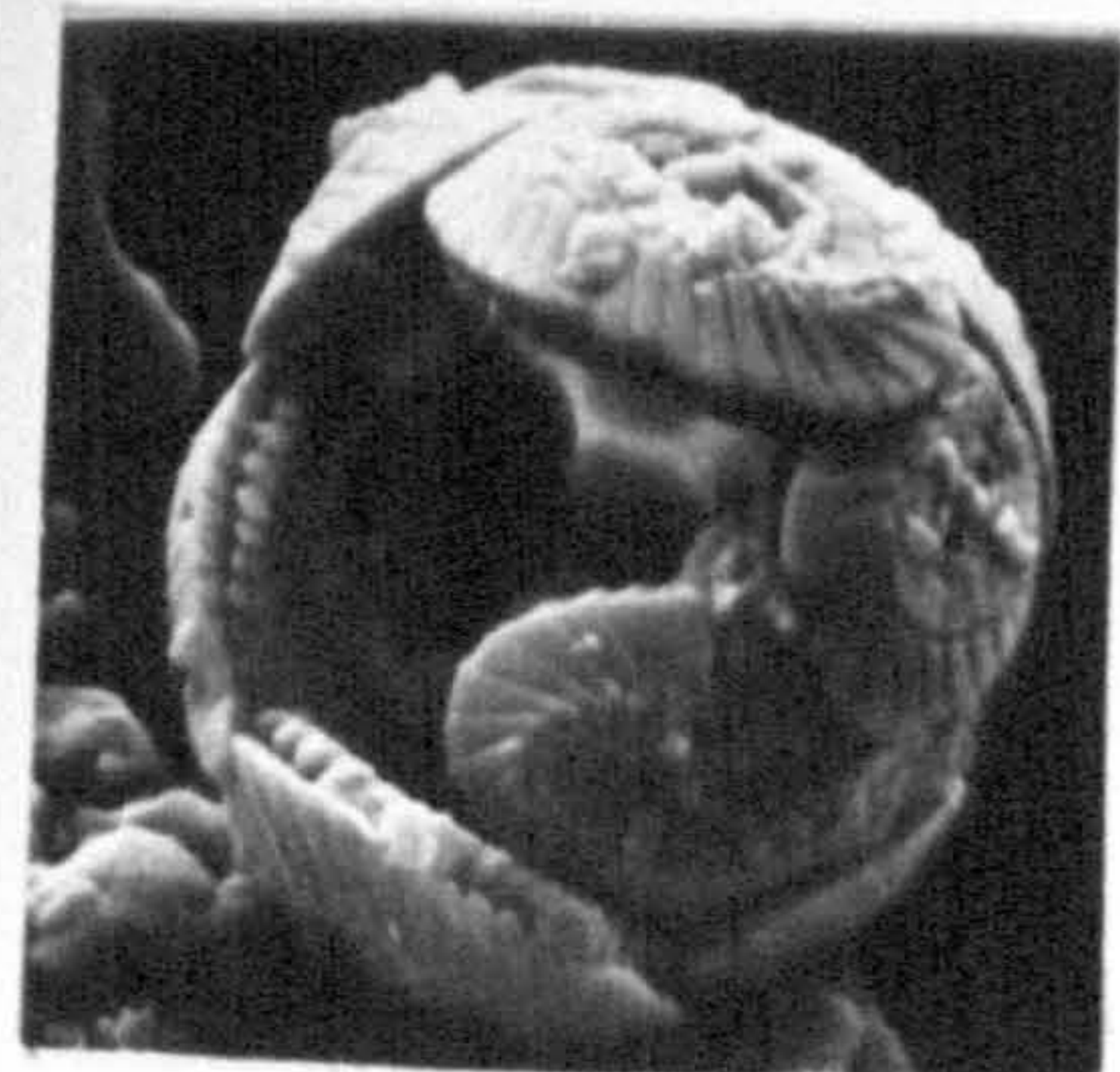
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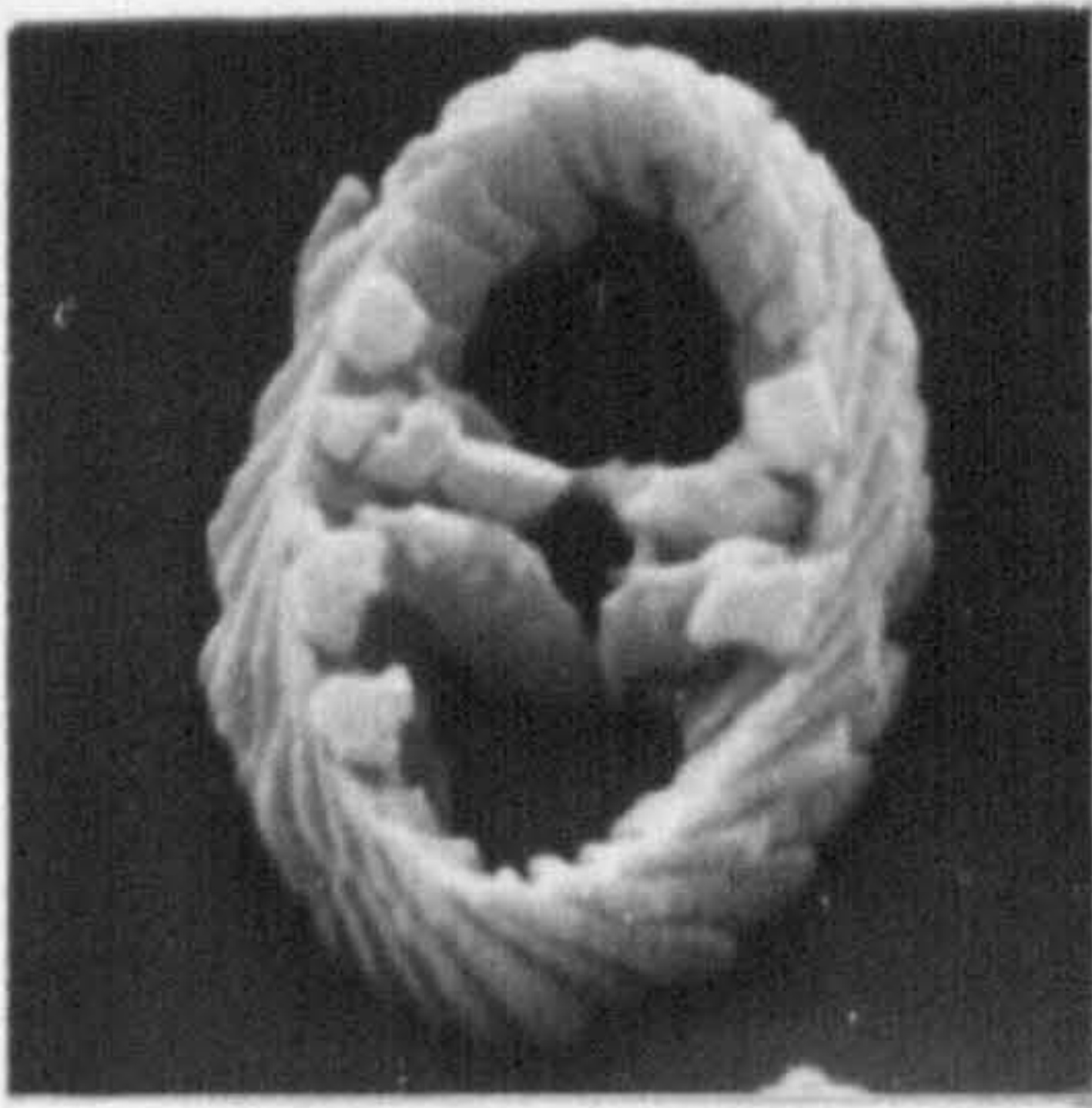


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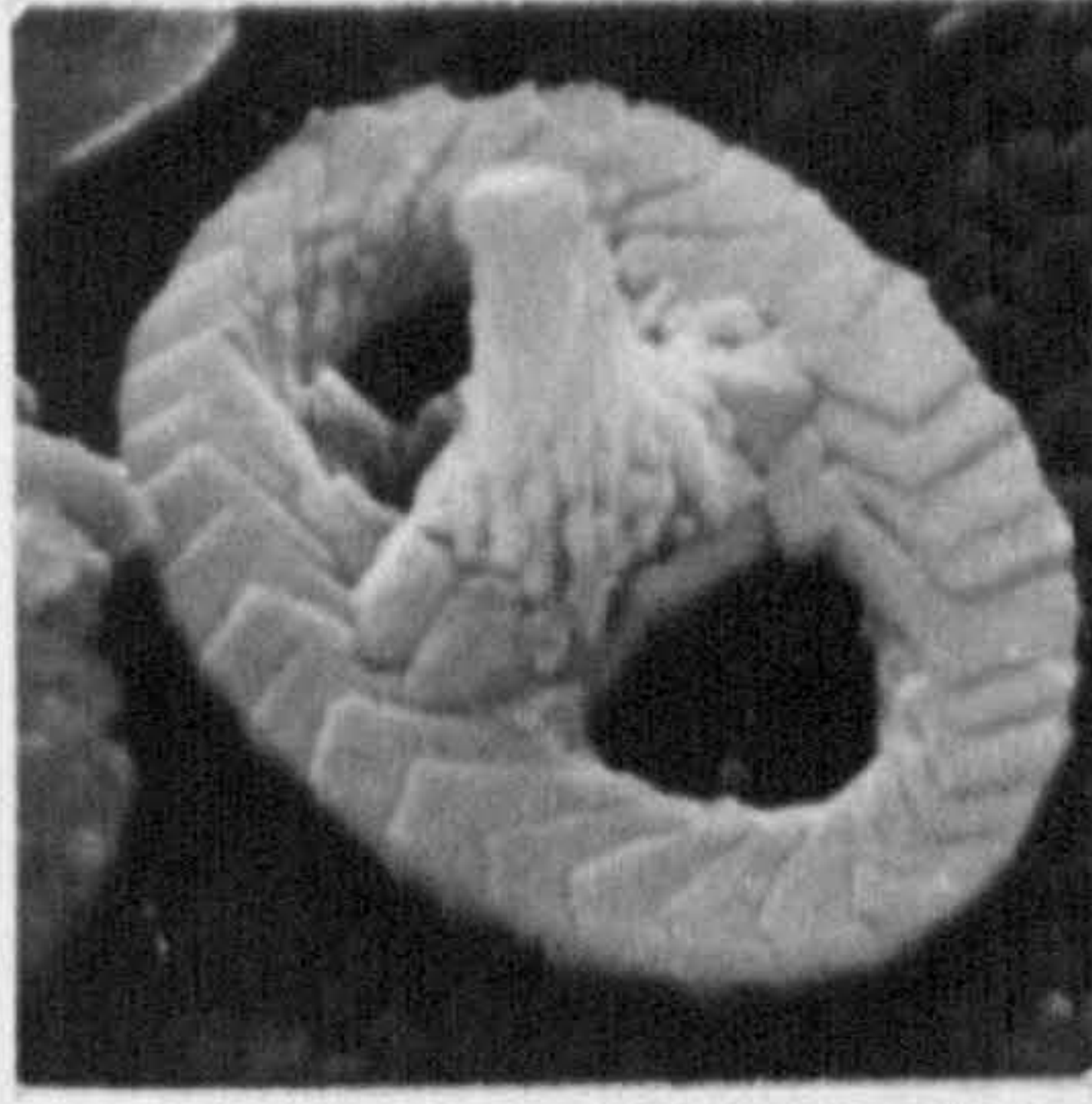
PLATE 2

- Fig. 1 Zygodiscus erectus (DEFLANDRE), Proximal view,
x 9,000, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-18.
- Fig. 2 Zygodiscus elegans GARTNER, Distal view,
x 10,000, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-23.
- Fig. 3 Zygodiscus noeli (ROOD, HAY & BARNARD), Distal side,
x 10,900, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-516-22.
- Fig. 4 Staurorhabdus quadriarcullus (NOEL), Proximal side,
x 9,700, Middle Bajocian, Brenha Rd., Neg. no. UCL-98-21.
- Fig. 5 Stauroolithites crux (DEFLANDRE), Distal side,
x 8,000, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-27.
- Fig. 6 Bennocyclus decussatus GRÜN, PRINS & ZWEILI, Proximal side,
x 8,600, Lower Bajocian, Brenha Rd., Neg. no. UCL-87-31.
- Fig. 7 Ellipsagelosphaera crucicentralis MEDD, Distal side,
x 5,800, Bathonian, Cap Mondego, Neg. no. UCL-630-16.
- Fig. 8 Ellipsagelosphaera crucicentralis MEDD, Proximal side,
x 6,400, Bathonian, Cap Mondego, Neg. no. UCL-604-27.
- Fig. 9 Ellipsagelosphaera crucicentralis MEDD, Distal side,
x 5,700, Bathonian, Cap Mondego, Neg. no. UCL-630-11.
- Fig. 10 Tubirhabdus patulus PRINS, Proximal side,
x 7,800, Bathonian, Cap Mondego, Neg. no. UCL-630-32.
- Fig. 11 Striatomarginis veterana (PRINS), Distal side,
x 8,500, Toarcian, Brenha Rd., Neg. no. UCL-59-4.
- Fig. 12. Striatomarginis veterana (PRINS), Proximal side,
x 5,000, Lower Bajocian, Brenha Rd., Neg. no. UCL-88-7.
- Fig. 13 Striatomarginis primitivus ROOD, HAY & BARNARD, Distal side,
x 7,900, Toarcian, Brenha Rd., Neg. no. UCL-60-11.
- Fig. 14 Striatomarginis primitivus ROOD, HAY & BARNARD, Proximal side,
x 6,900, Toarcian, Brenha Rd., Neg. no. UCL-66-7.
- Fig. 15 Striatomarginis primitivus ROOD, HAY & BARNARD, Distal side,
x 9,500, Lias, Peniche, Neg. no. UCL-539-15.

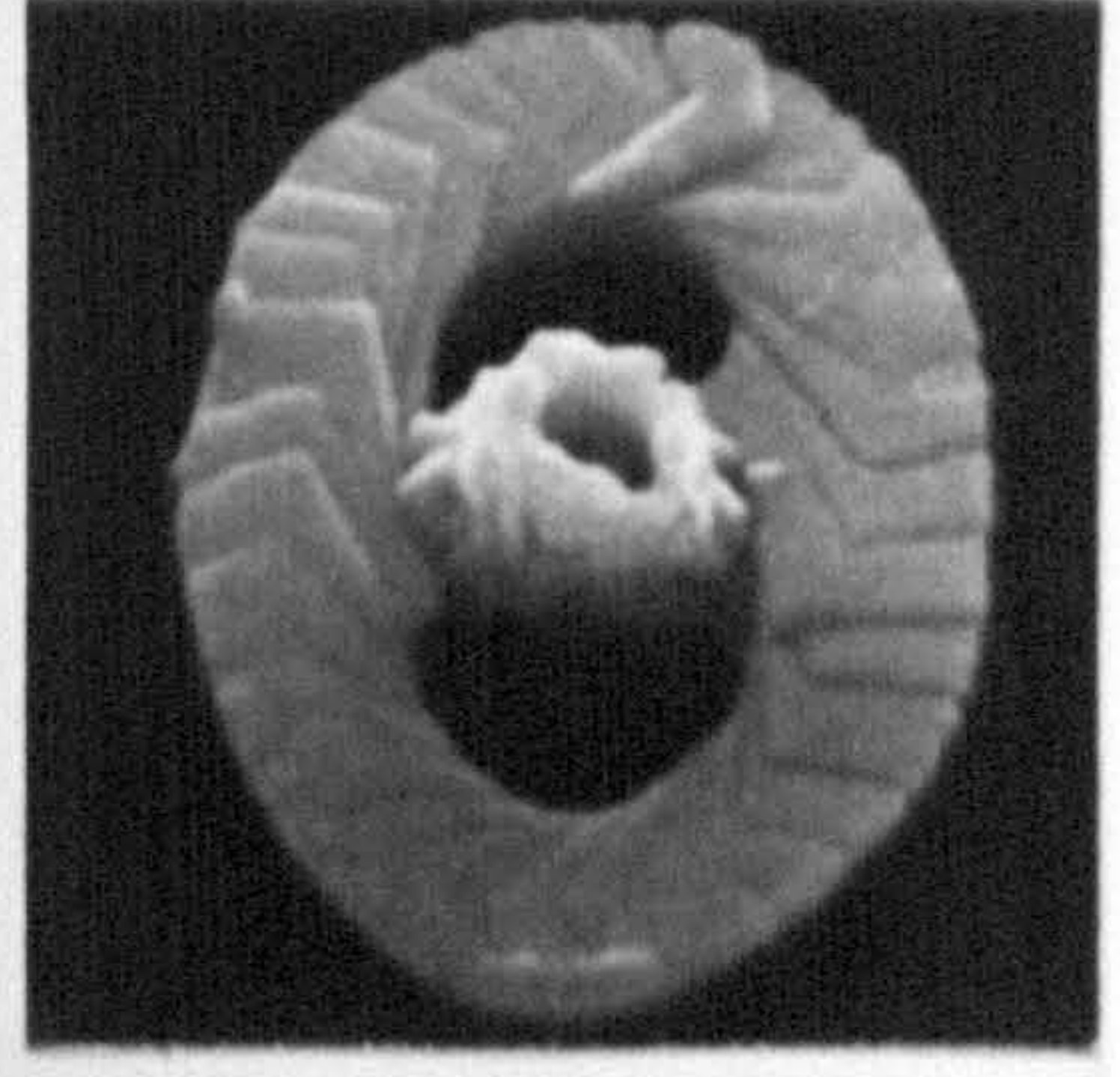
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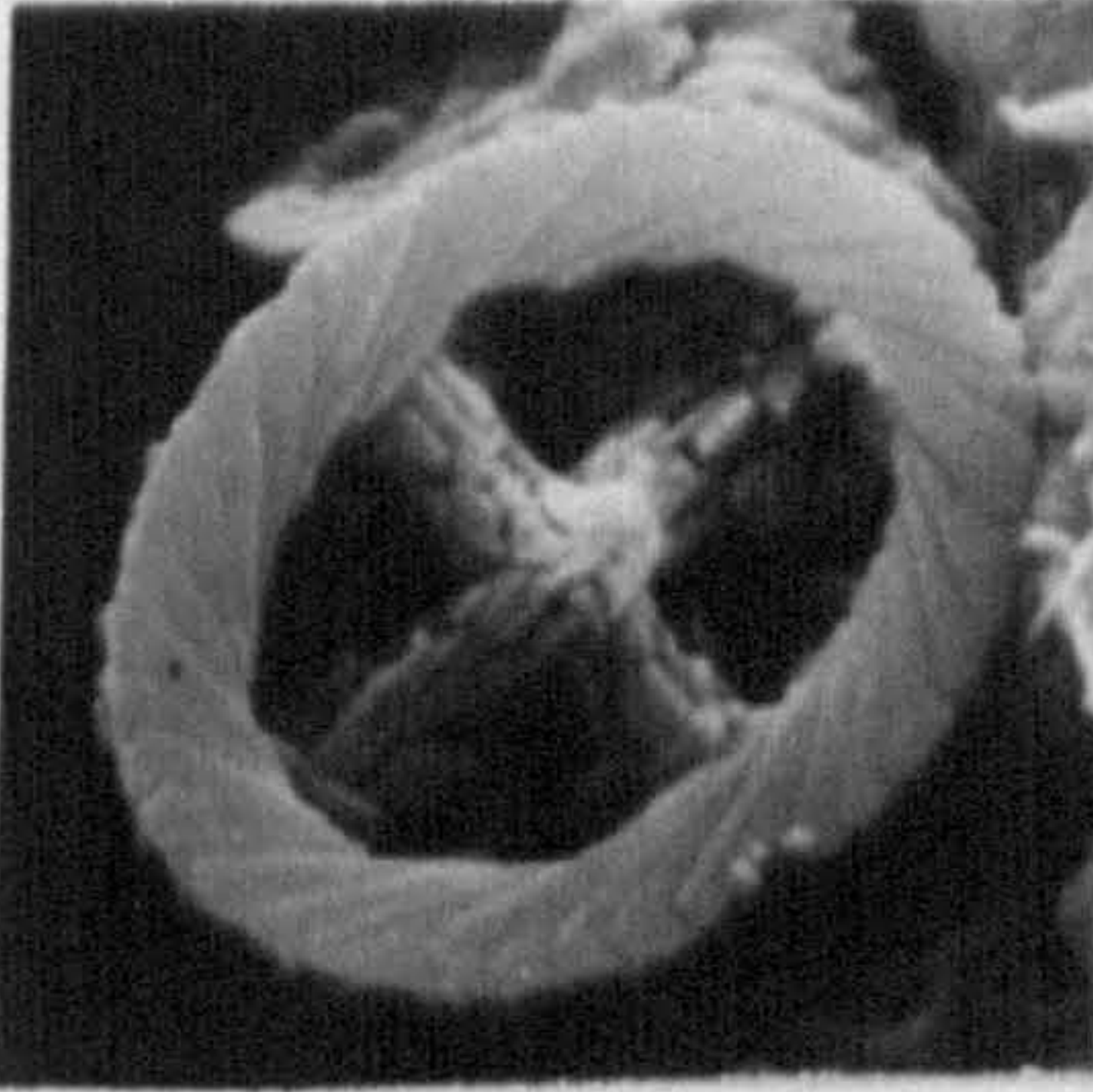
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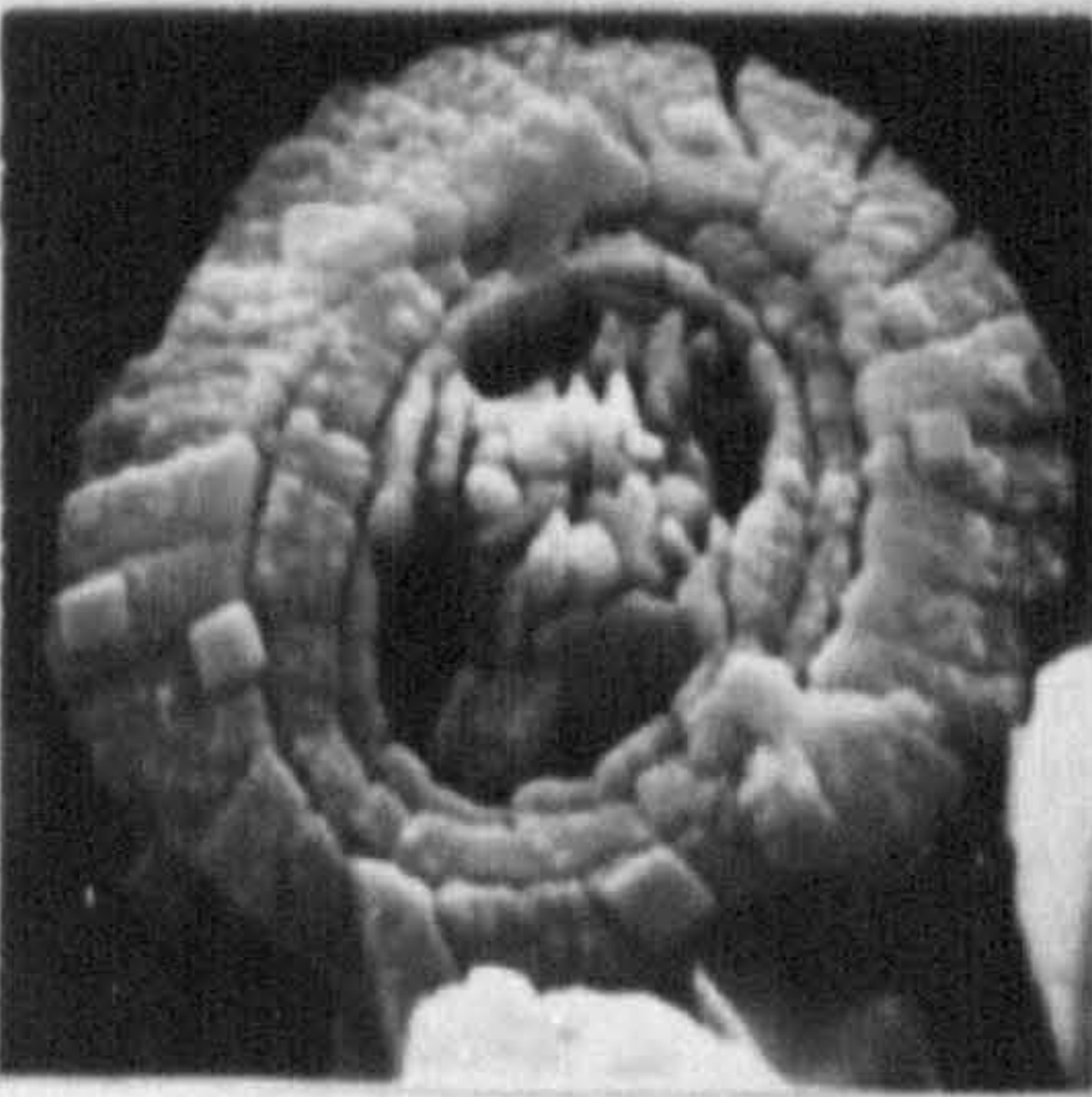
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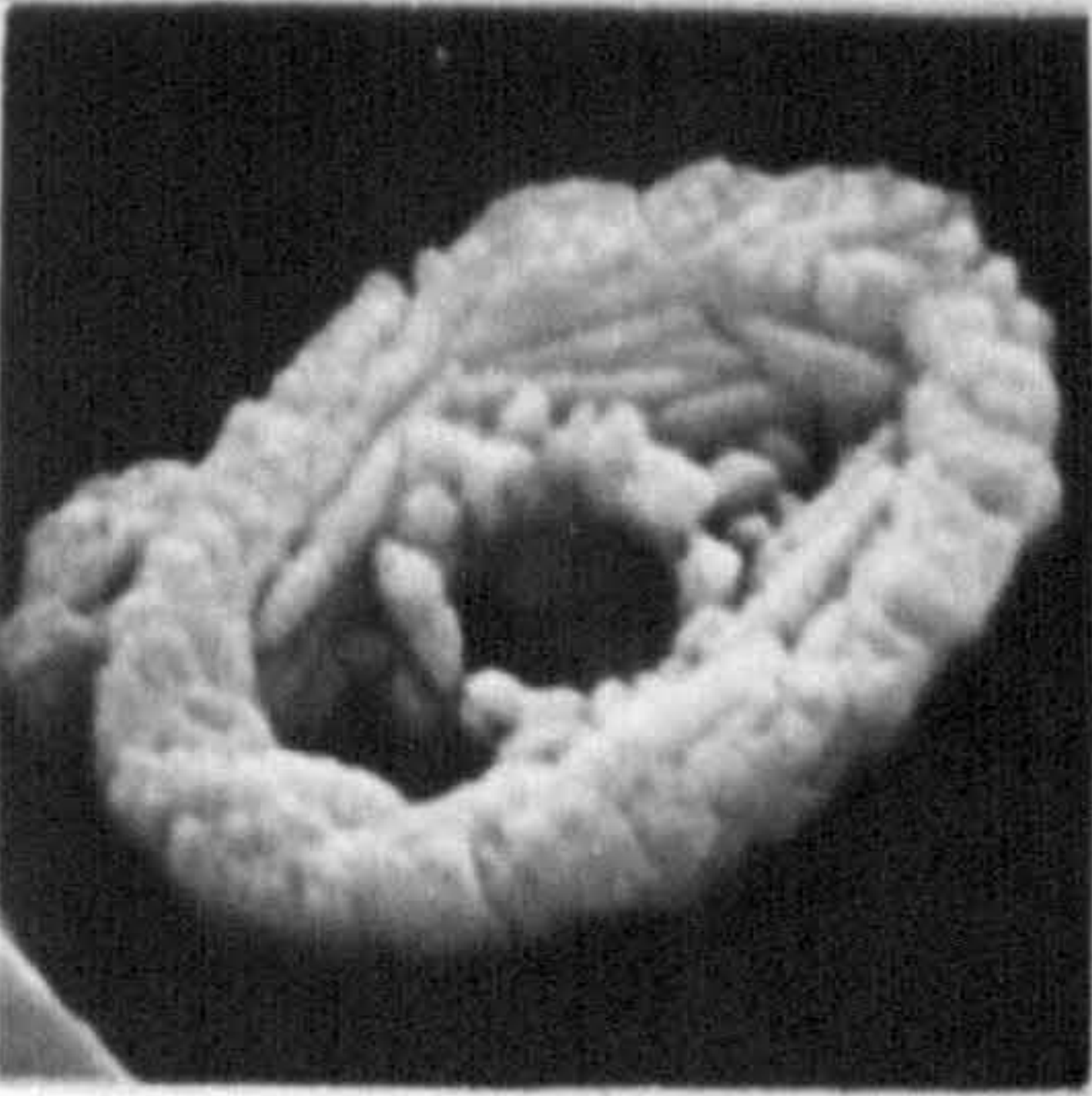
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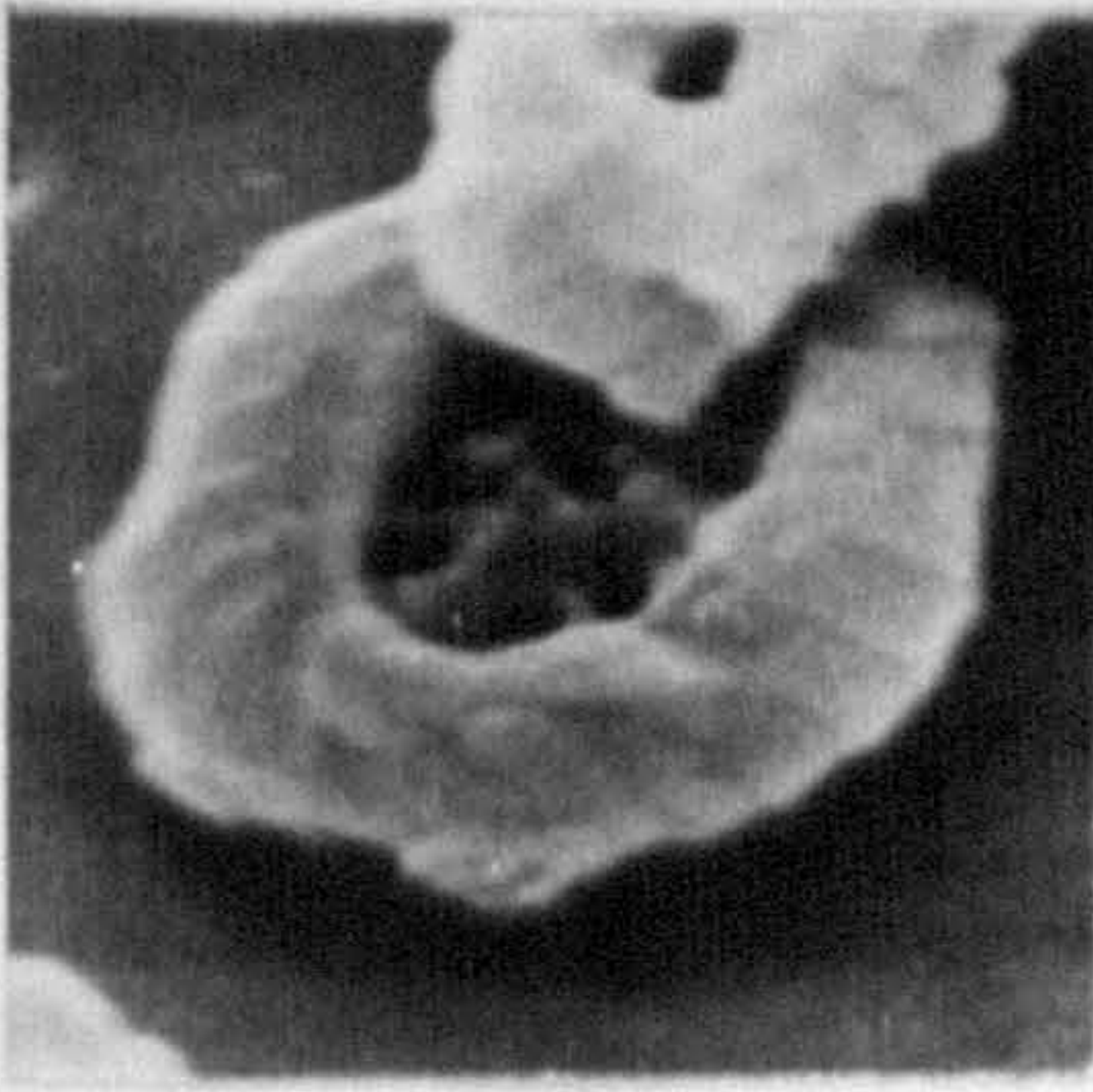
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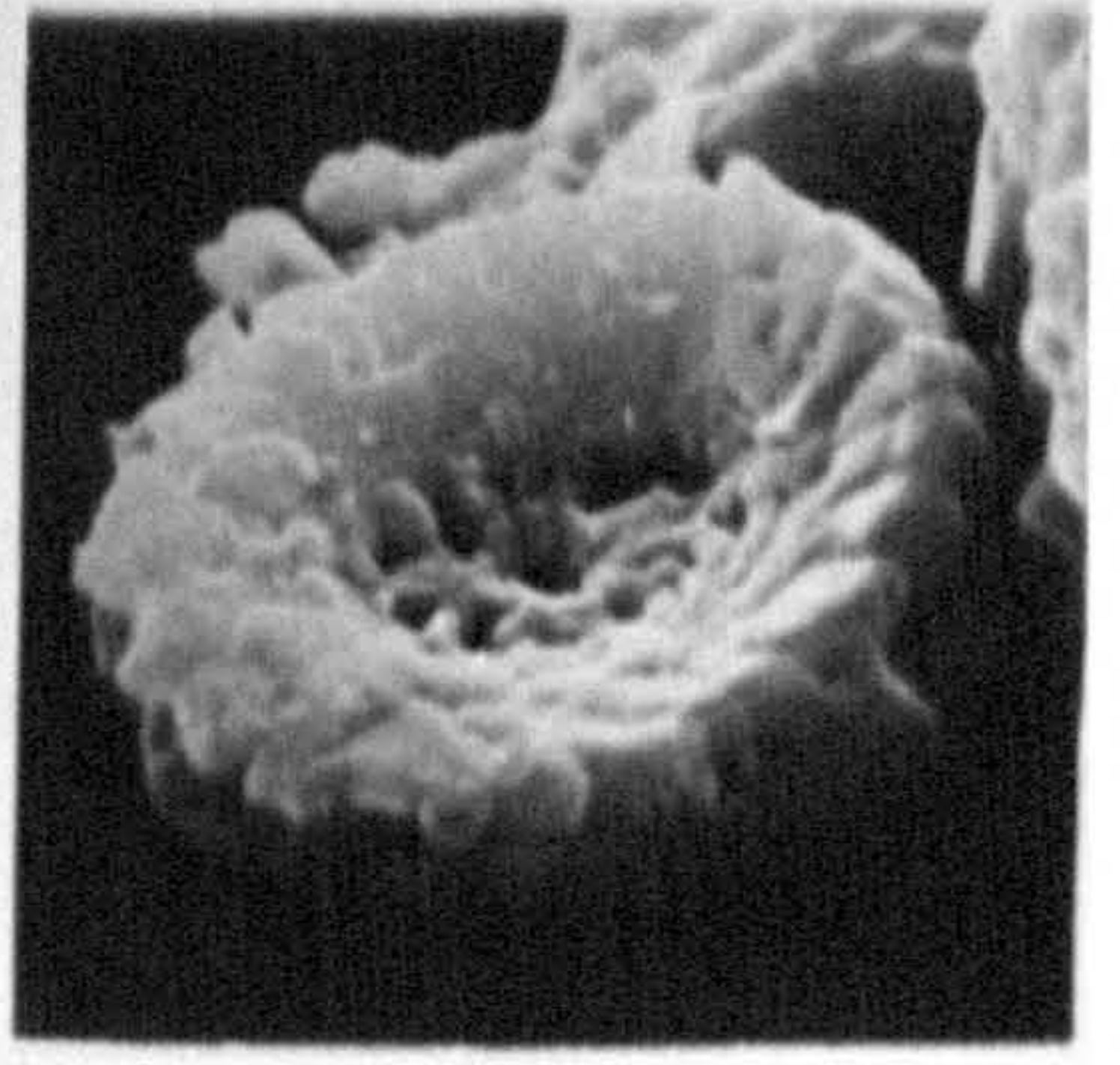
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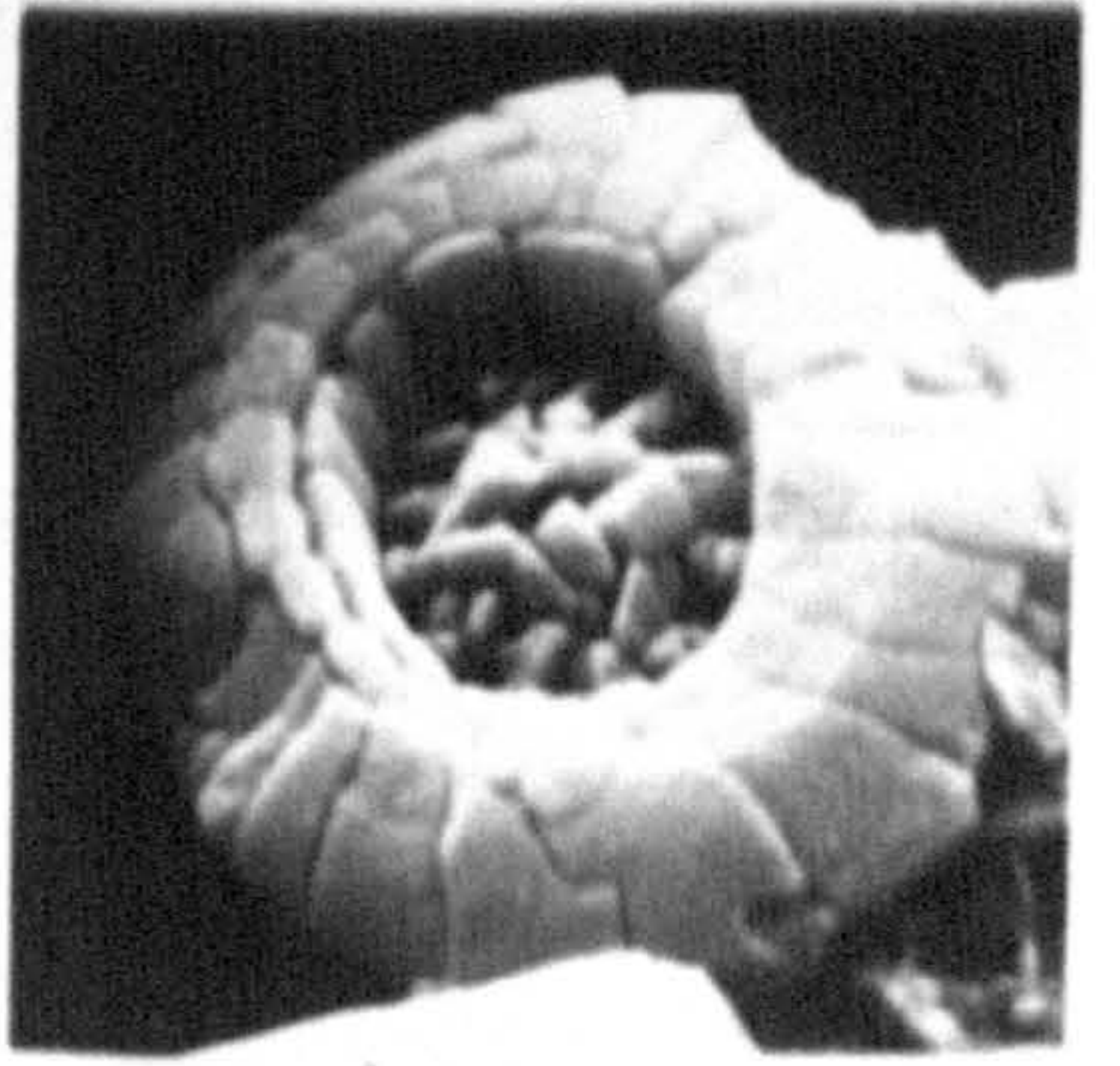
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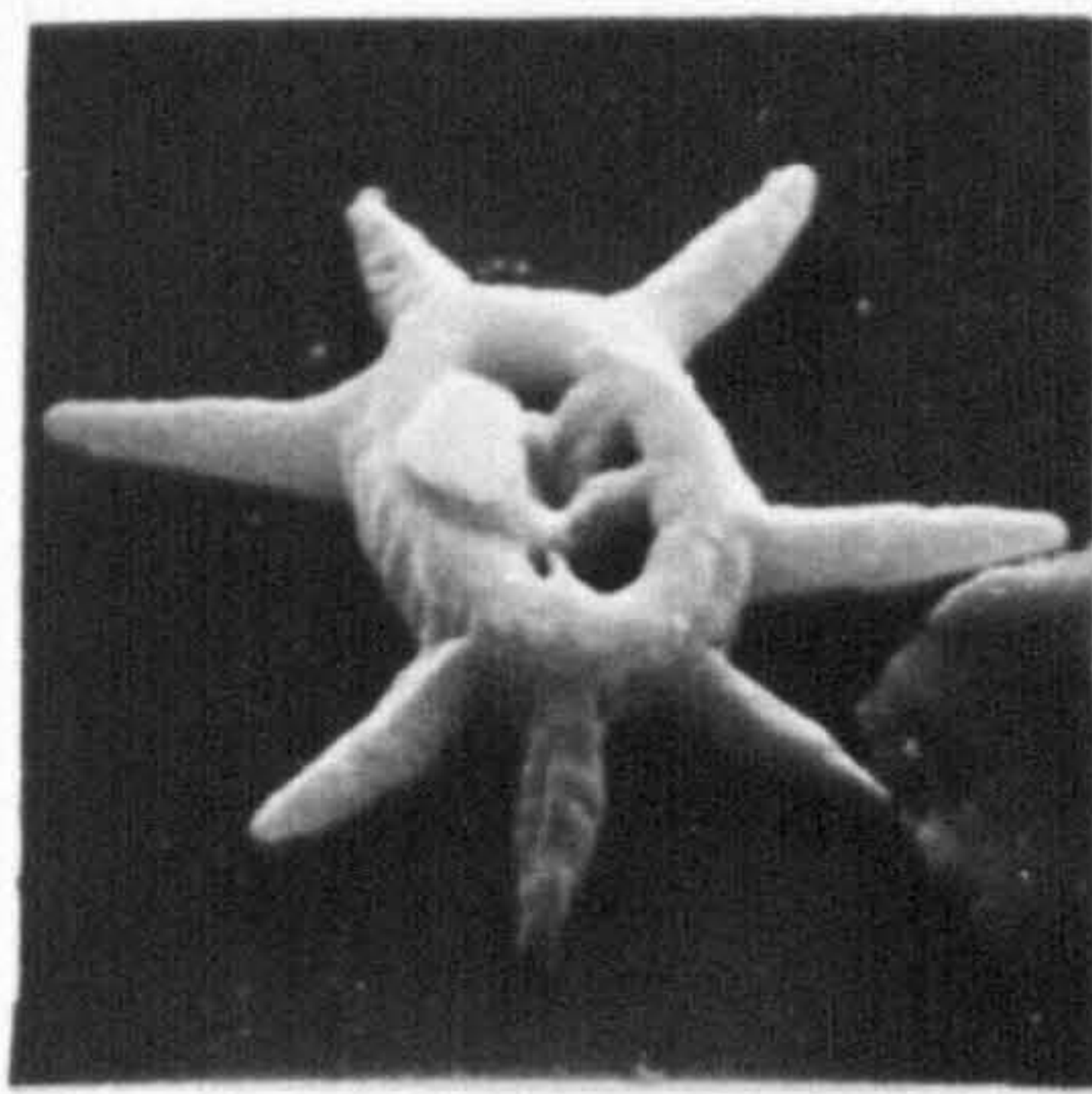


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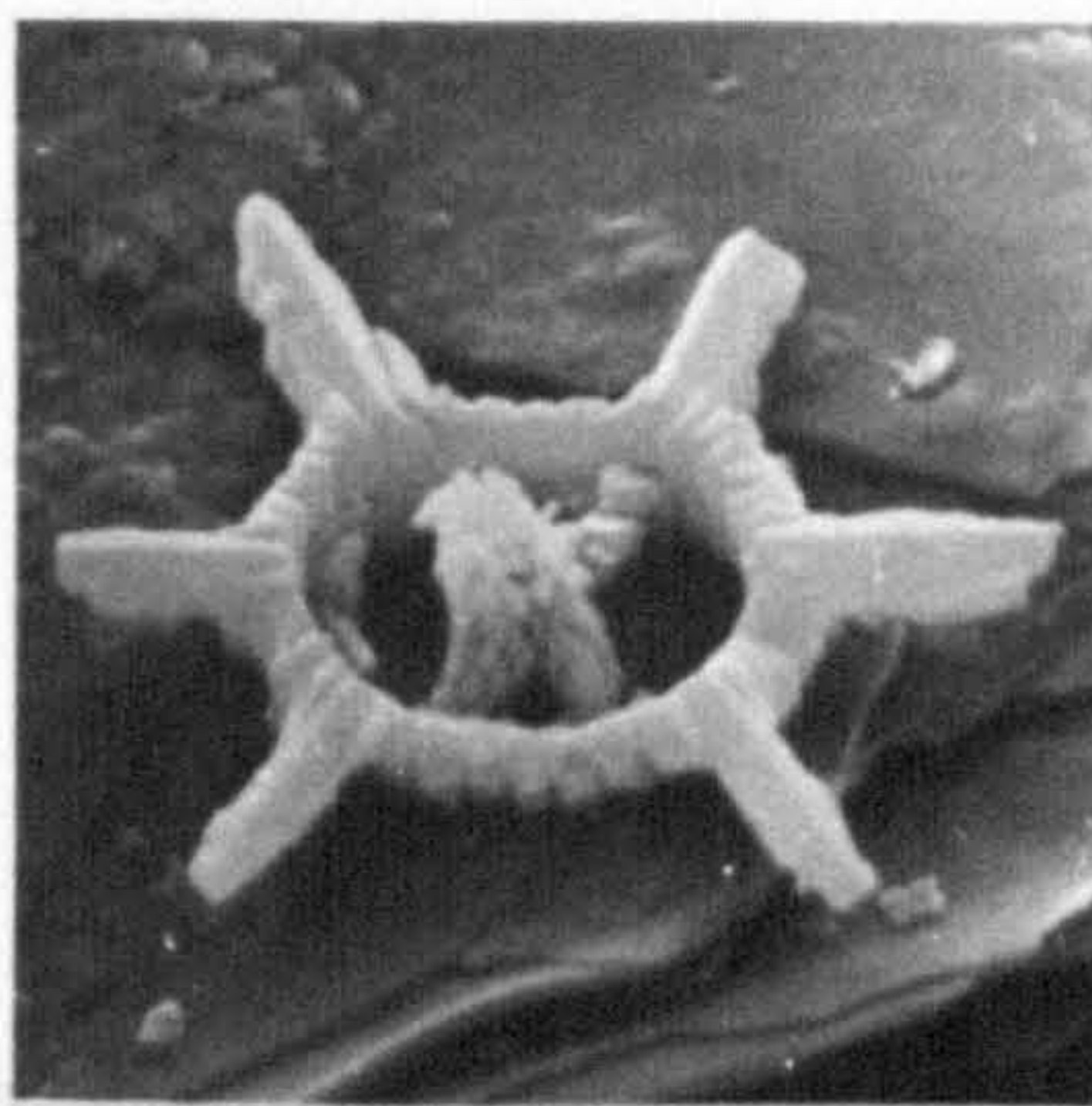
PLATE 3

- Fig. 1 Stephanolithion bigoti DEFLANDRE, Proximal side,
x 5,600, Lower Oxfordian, Skye, Neg. no. UCL-451-23.
- Fig. 2 Stephanolithion bigoti DEFLANDRE, Distal side,
x 5,800, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-27.
- Fig. 3 Stephanolithion speciosum DEFLANDRE, Distal side,
x 5,900, Bathonian, Brenha Rd., Neg. no. UCL-654-16.
- Fig. 4 Stephanolithion speciosum var. octum ROOD & BARNARD, Distal side,
x 5,200, Bathonian, Brenha Rd., Neg. no. UCL-103-27.
- Fig. 5 Parhabdolithus sp. Proximal side,
x 6,900, Lower Pliensbachian, Brenha Rd., Neg. no. UCL-57-2.
- Fig. 6 Parhabdolithus sp. Distal side,
x 5,300, Lower Pliensbachian, Brenha Rd., Neg. no. UCL-57-3.
- Fig. 7 Cretarhabdus sp. 1, Distal side,
x 7,000, Middle Bajocian, Brenha Rd., Neg. no. UCL-98-29.
- Fig. 8 Cretarhabdus sp. 1, Proximal side,
x 4,300, Middle Bajocian, Brenha Rd., Neg. no. UCL-98-27.
- Fig. 9 Cretarhabdus sp. 1, Distal side,
x 4,600, Middle Bajocian, Brenha Rd., Neg. no. UCL-98-15.
- Fig. 10 Cretarhabdus sp. 2, Proximal side,
x 7,400, Middle Bajocian, Brenha Rd., Neg. no. UCL-97-25.
- Fig. 11 Calyculus pugnatum GRÜN, PRINS & ZWEILI, Distal side,
x 4,300, Upper Pliensbachian, Brenha Rd., Neg. no. UCL-64-2.
- Fig. 12 Calyculus cribrum NOEL, Distal side
x 6,300, Lower Pliensbachian, Brenha Rd., Neg. no. UCL-56-6.
- Fig. 13 Podorhabdus macrogranulatus PRINS, Proximal side,
x 5,300, Upper Pliensbachian, Brenha Rd., Neg. no. UCL-62-19.
- Fig. 14 Crepidolithus crassus (DEFLANDRE), Proximal side,
x 4,700, Upper Pliensbachian, Brenha Rd., Neg. no. UCL-64-13.
- Fig. 15 Crepidolithus crassus (DEFLANDRE), Distal side,
x 4,200, Lower Pliensbachian, Brenha Rd., Neg. no. UCL-63-37.

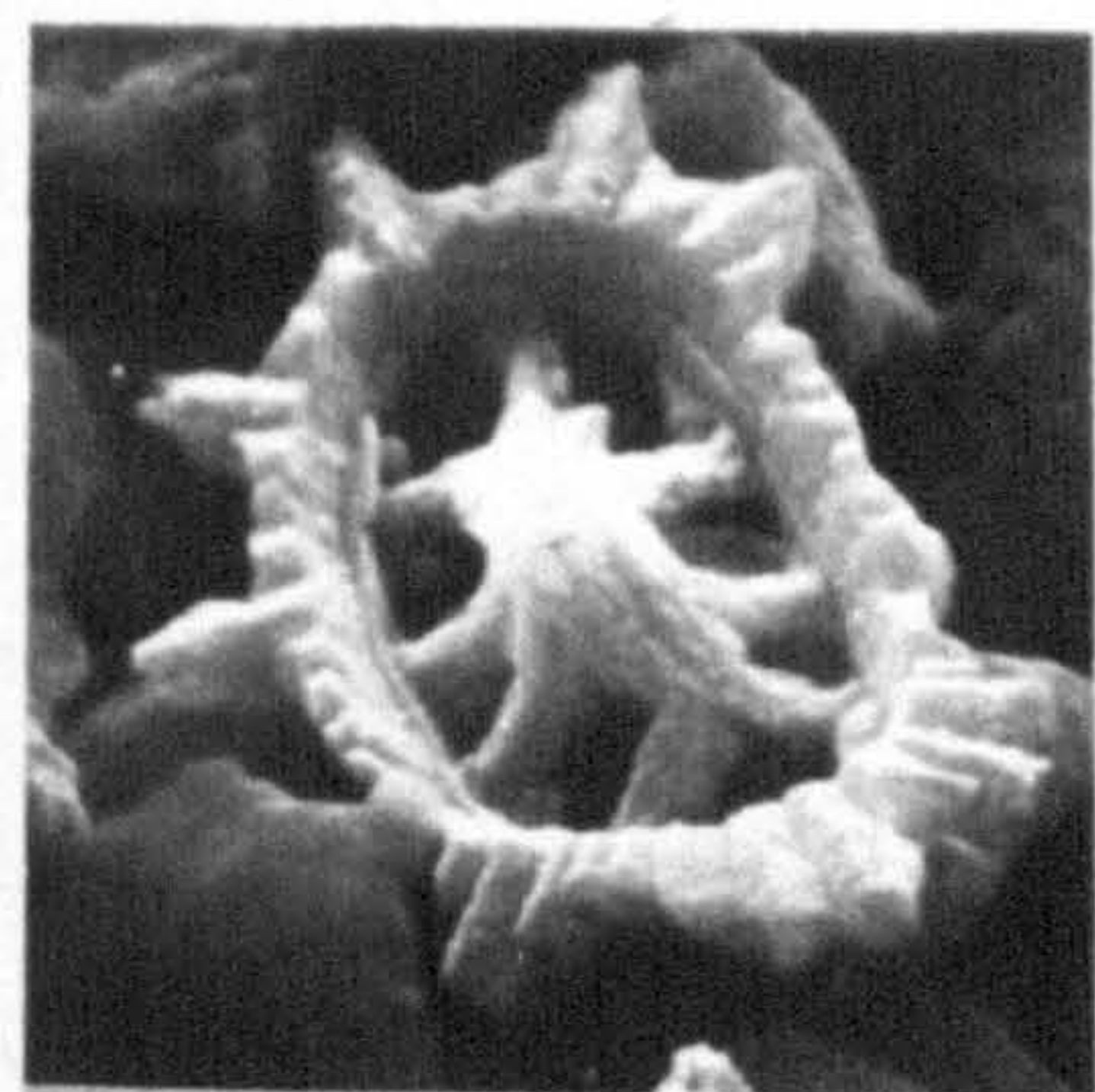
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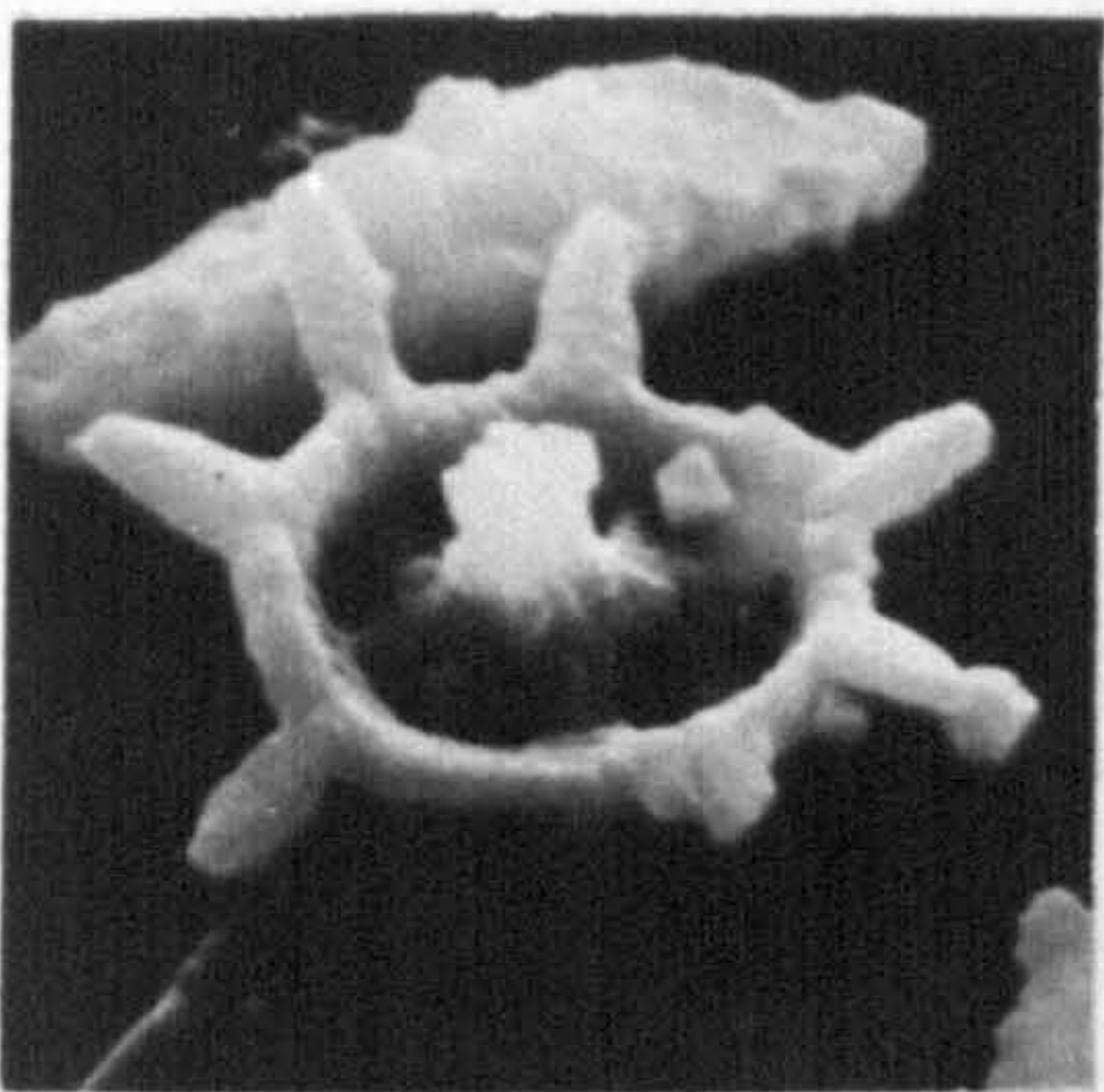
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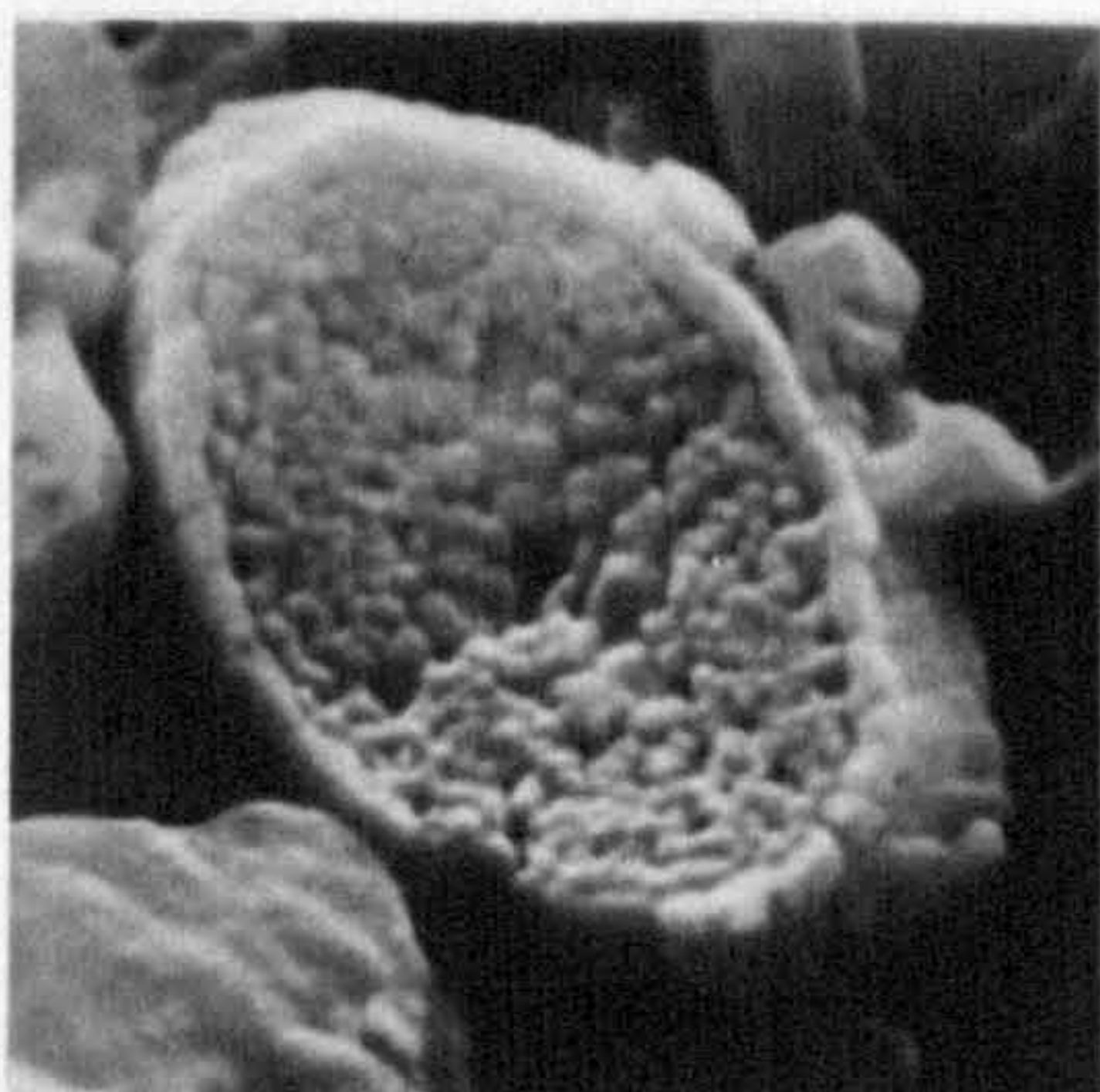
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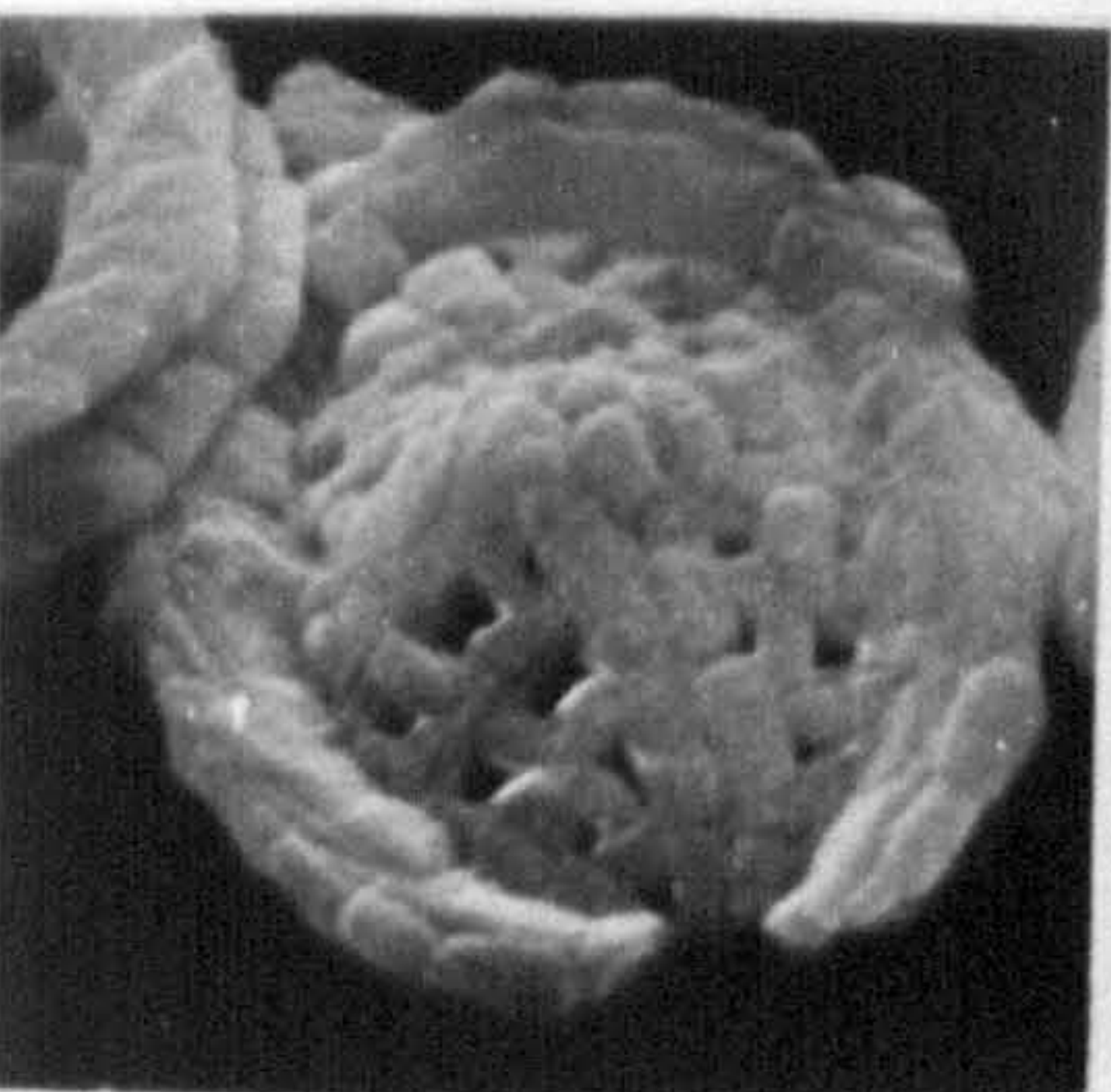
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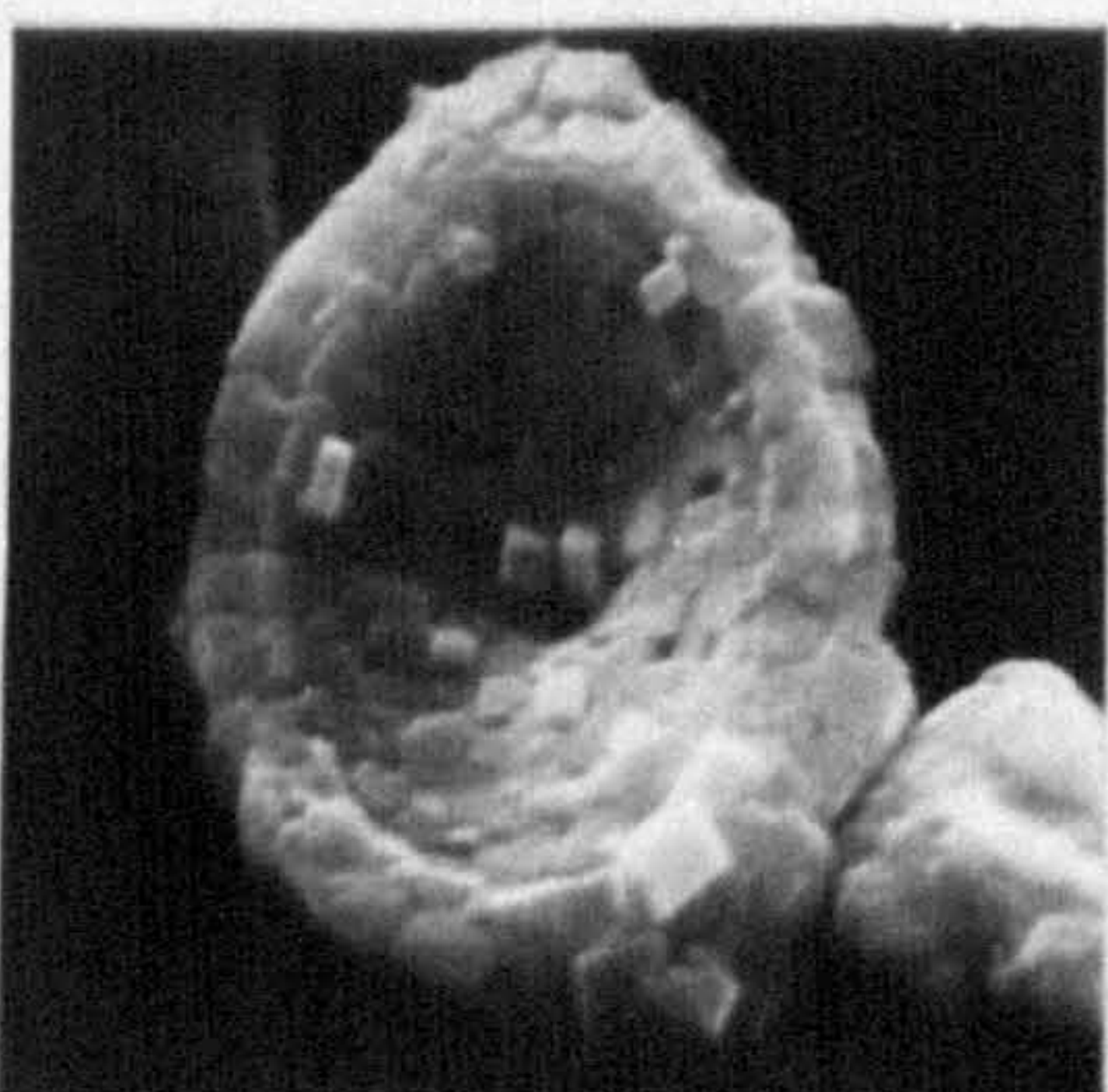
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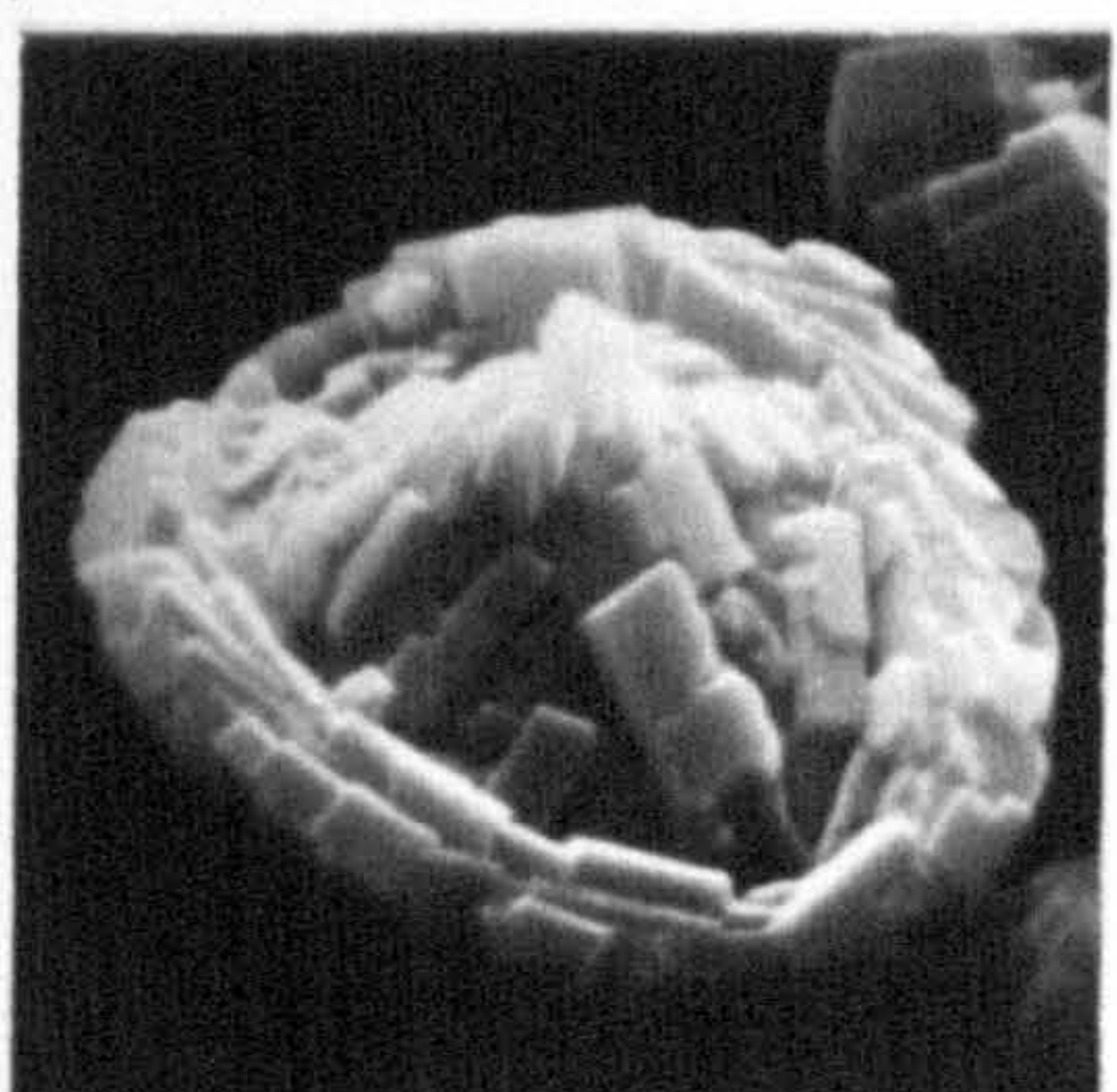
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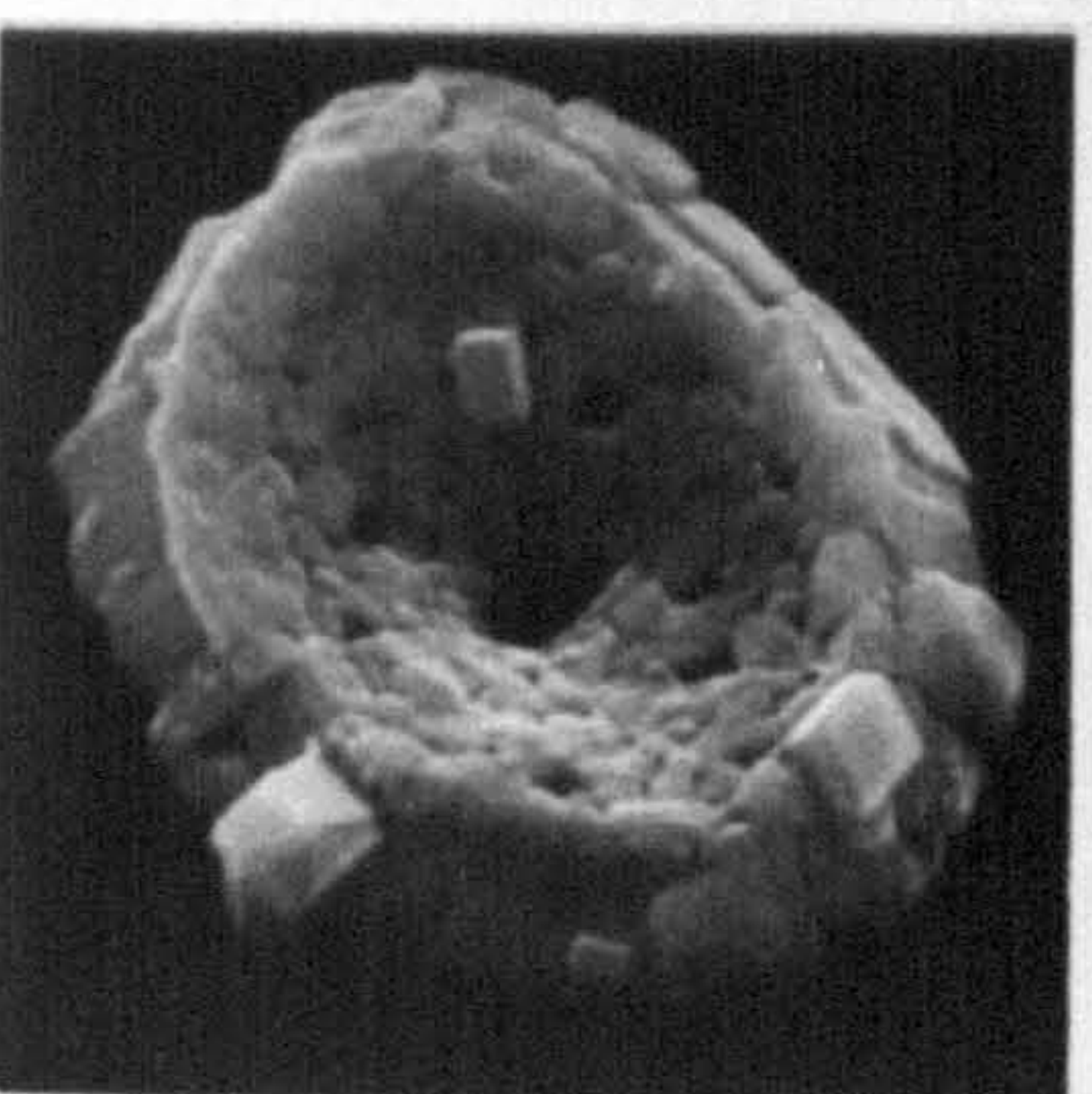
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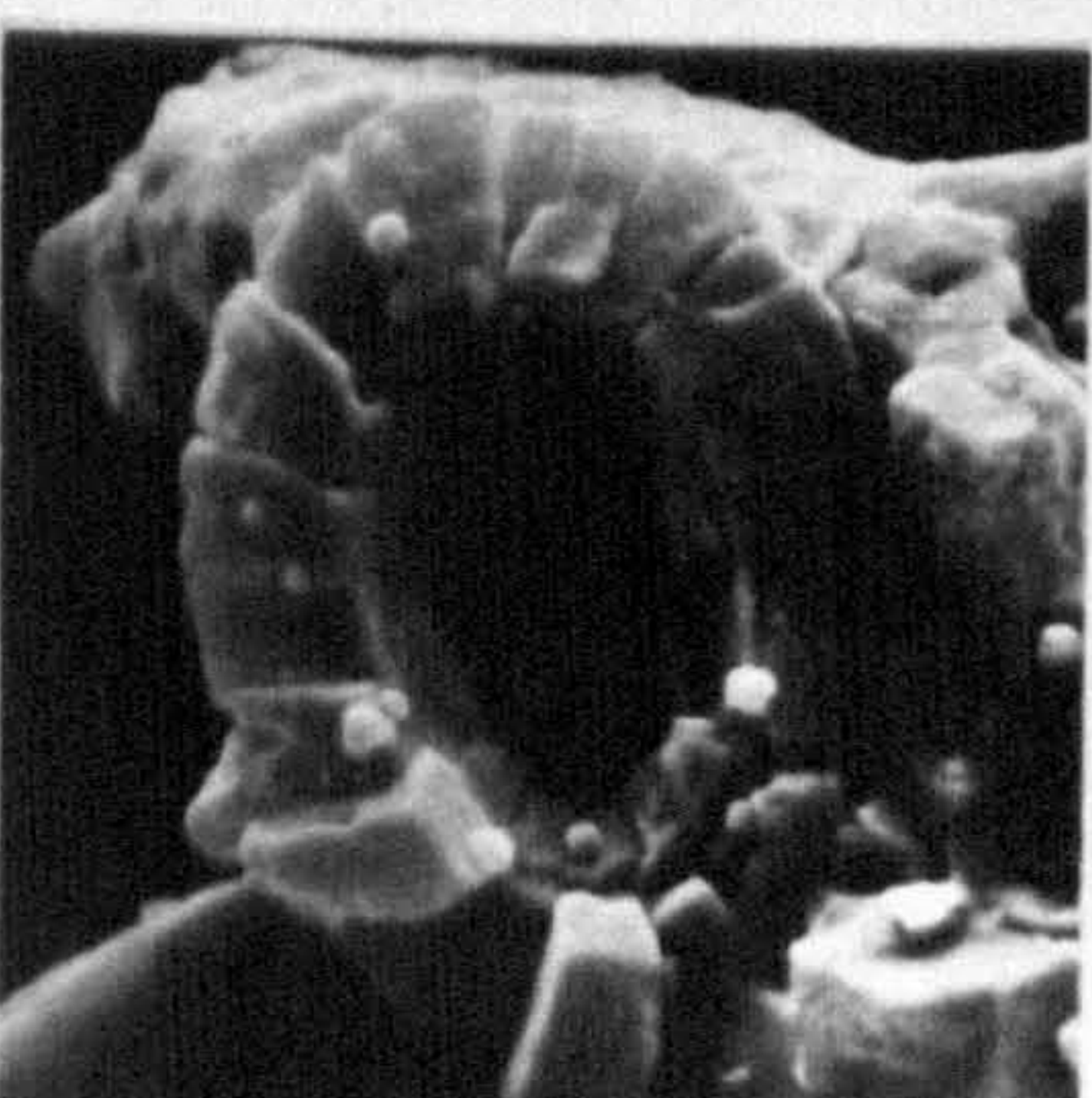
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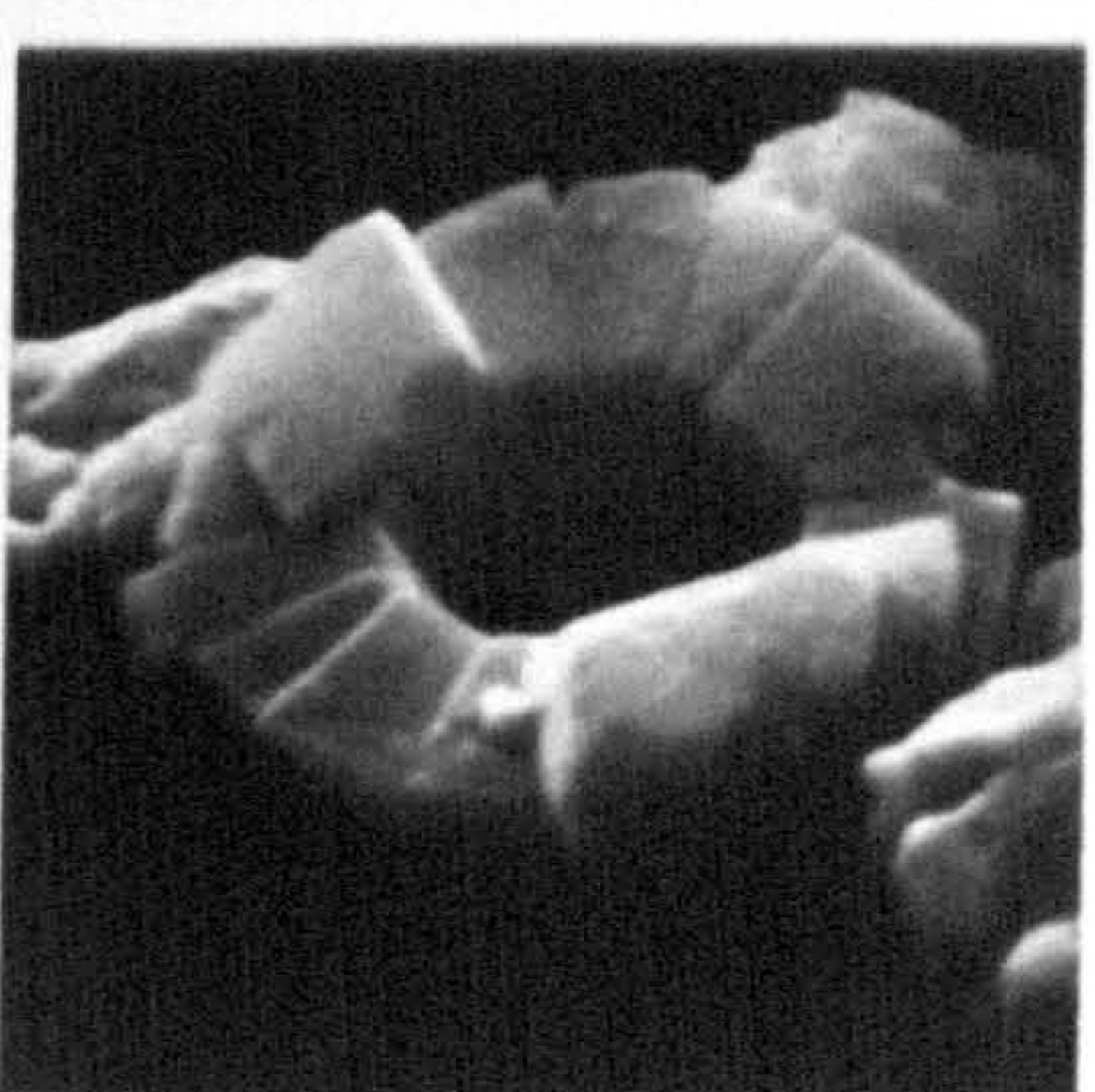
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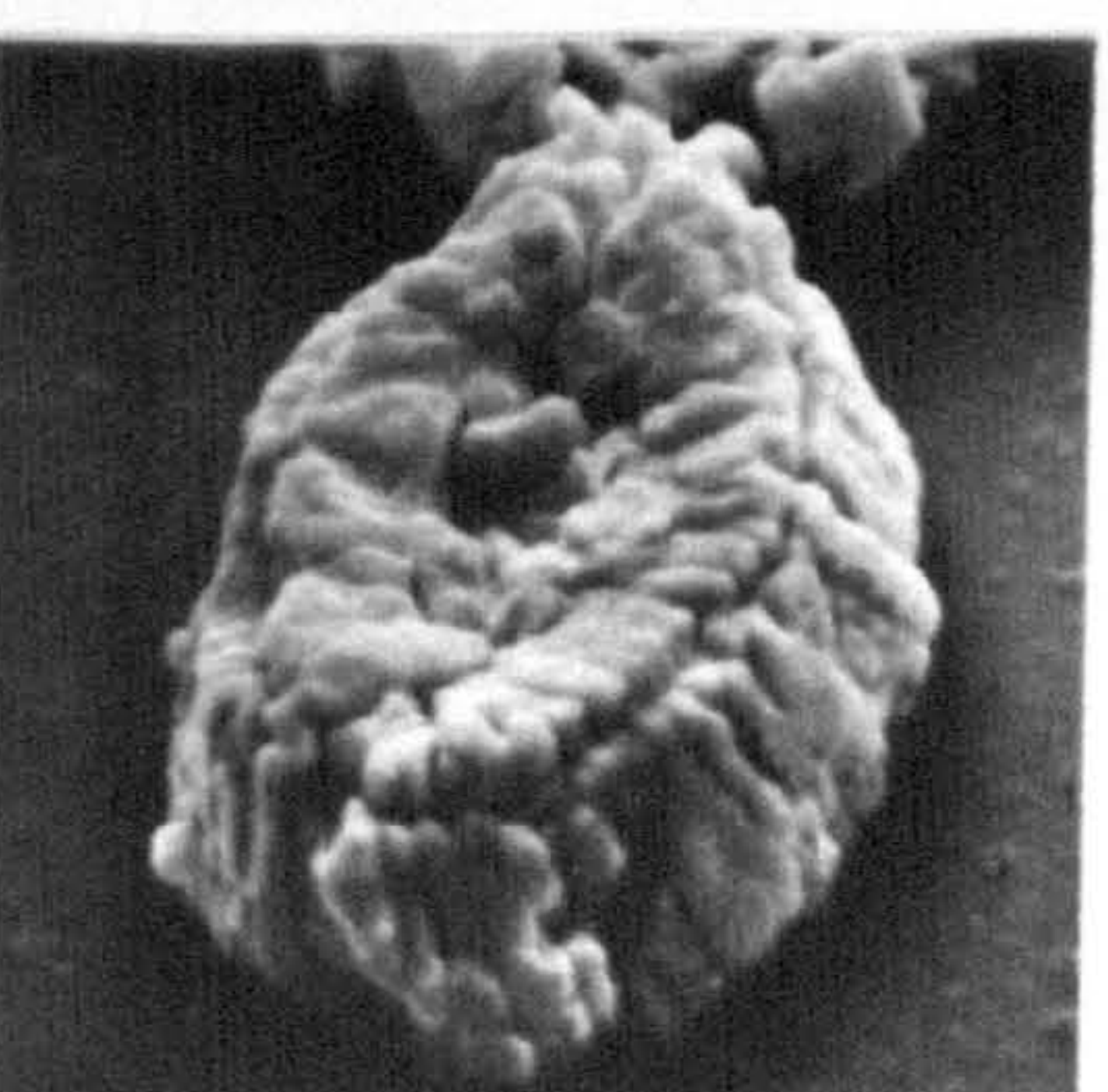
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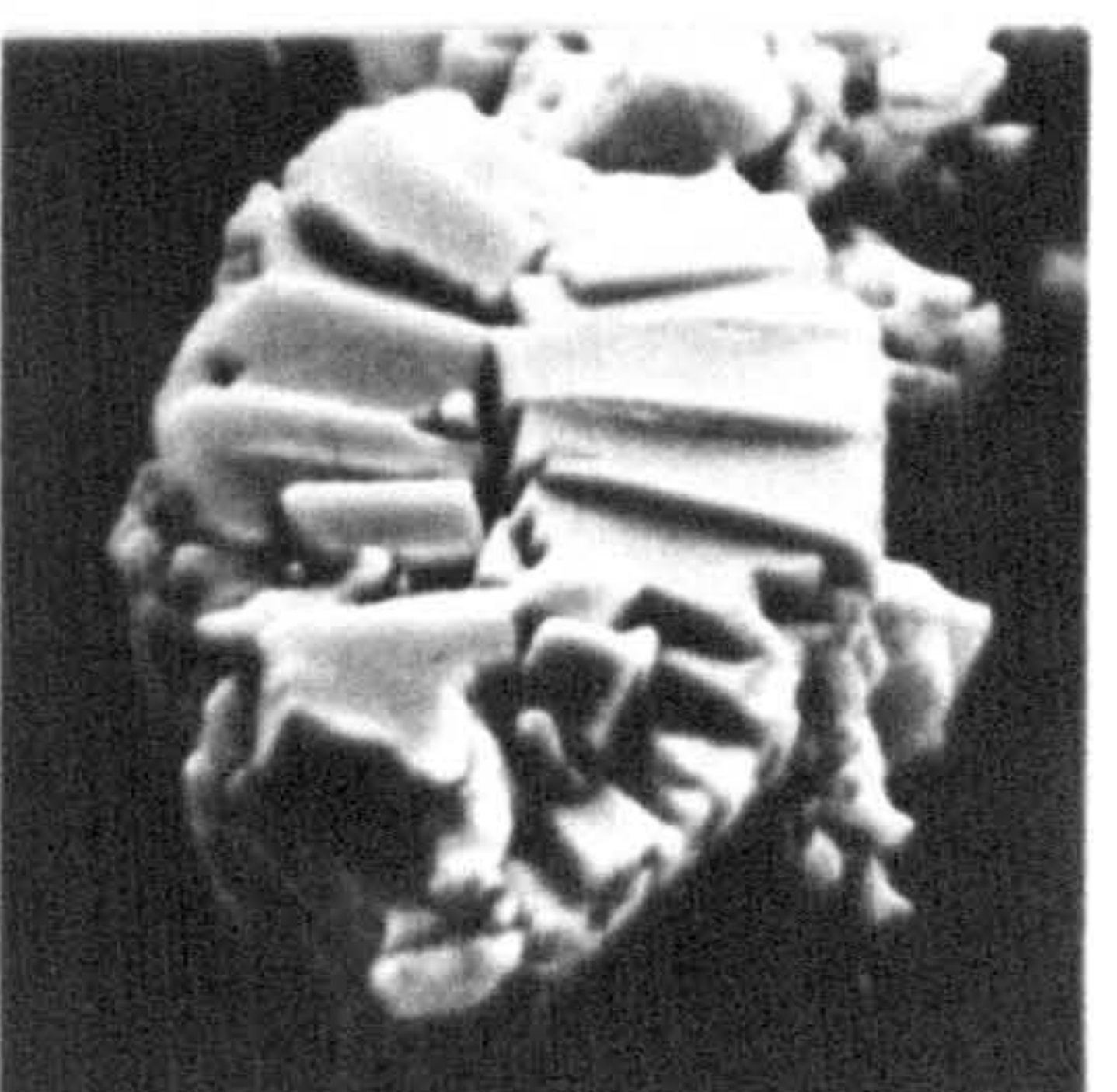
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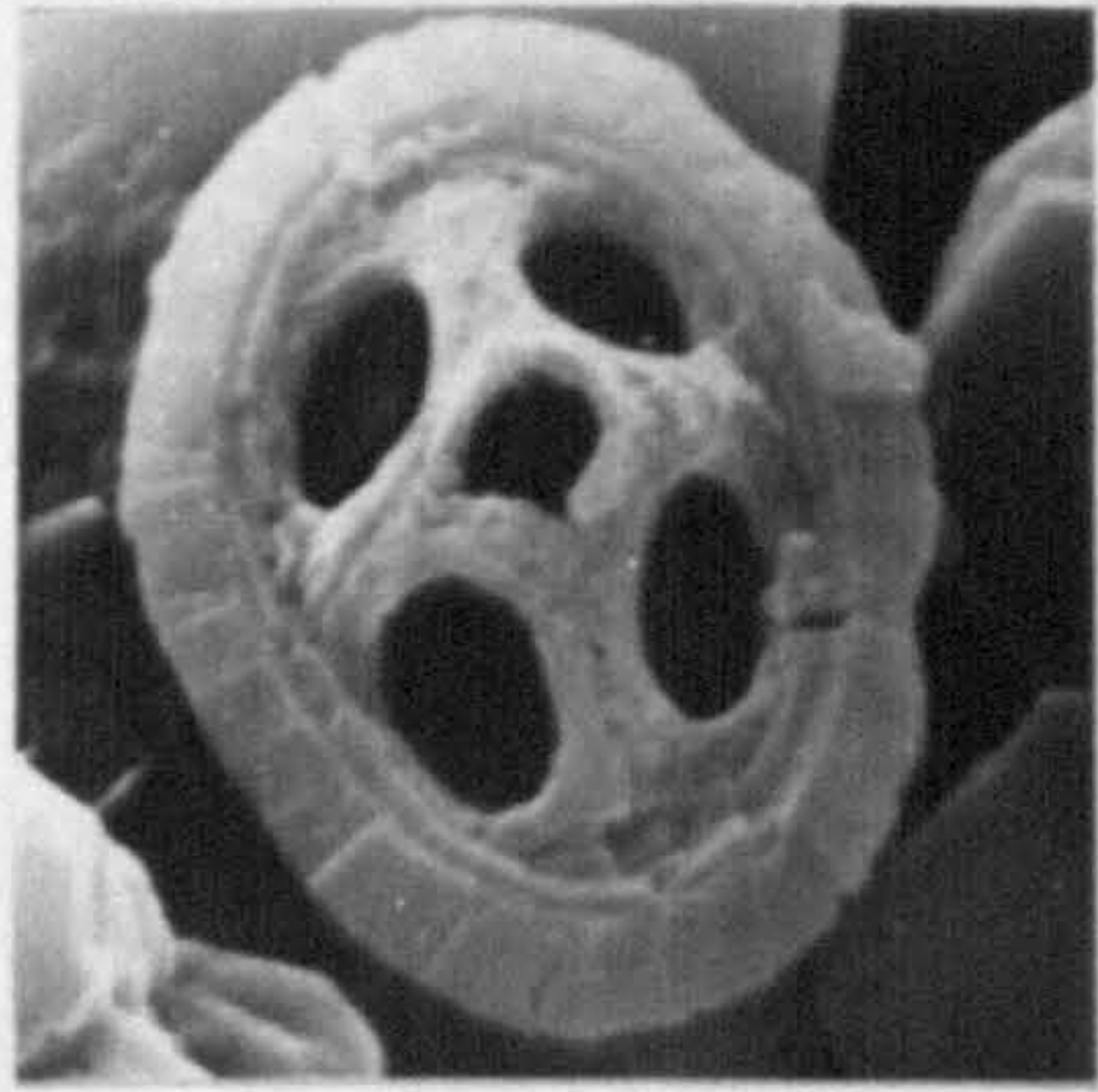


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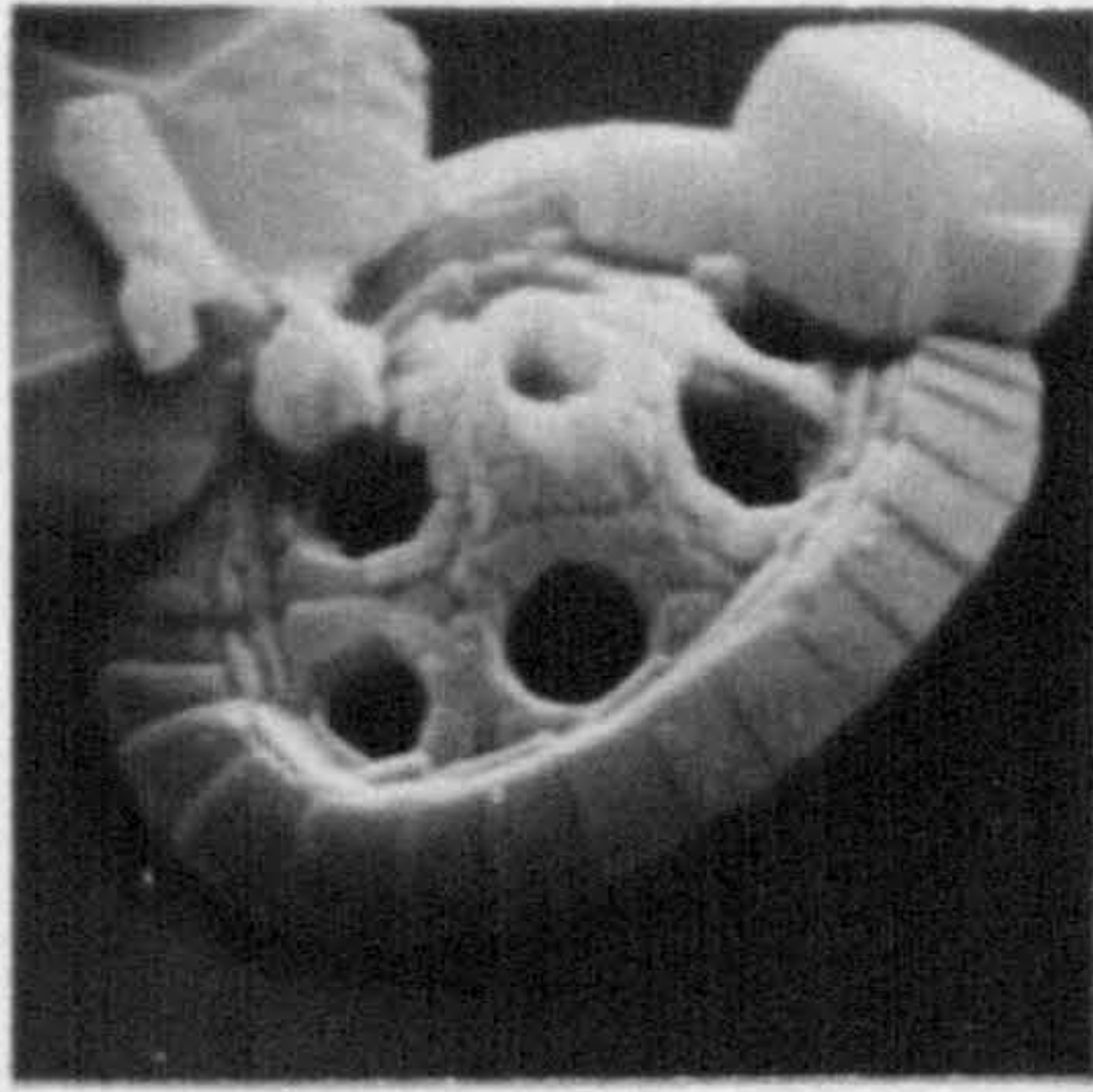
PLATE 4

- Fig. 1 Podorhabdus cylindratus NOEL, Distal side,
x 5,400, Upper Callovian, Skye, Neg. no. UCL-503A-3.
- Fig. 2 Hexapodorhabdus cuvillieri NOEL, Distal side,
x 6,700, Lower Oxfordian, Skye, Neg. no. UCL-451-24.
- Fig. 3 Hexapodorhabdus cuvillieri NOEL, Proximal side,
x 6,900, Lower Oxfordian, Skye, Neg. no. UCL-451-26.
- Fig. 4 Octopodorhabdus decussatus (MANIVIT), Proximal side,
x 4,700, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-505-4.
- Fig. 5 Ethmorhabdus gallicus NOEL, Distal side,
x 4,200, Upper Callovian, Skye, Neg. no. UCL-446-4.
- Fig. 6 Ethmorhabdus gallicus NOEL, Proximal side,
x 4,400, Lower Oxfordian, Skye, Neg. no. UCL-451-11.
- Fig. 7 Polypodorhabdus madingleyensis BLACK, Distal side,
x 4,800, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-654-22.
- Fig. 8 Polypodorhabdus madingleyensis BLACK, Distal side,
x 5,100, Upper Callovian, Skye, Neg. no. UCL-434-40.
- Fig. 9 Polypodorhabdus madingleyensis BLACK, Proximal side,
x 7,000, Upper Callovian, Skye, Neg. no. UCL-451-12.
- Fig. 10 Retecapsa schizobrachiata (GARTNER), Distal side,
x 5,600, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-515-14.
- Fig. 11 Retecapsa schizobrachiata (GARTNER), Proximal side,
x 5,400, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-516-8.
- Fig. 12 Retecapsa angustiforata BLACK, Proximal side,
x 5,800, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-637-24.
- Fig. 13 Perrisocyclus sp., Distal side,
x 5,100, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-7.
- Fig. 14 Perrisocyclus sp., Proximal side,
x 5,700, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-516-18.
- Fig. 15 Perrisocyclus sp., Distal side,
x 5,600, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-516-35.

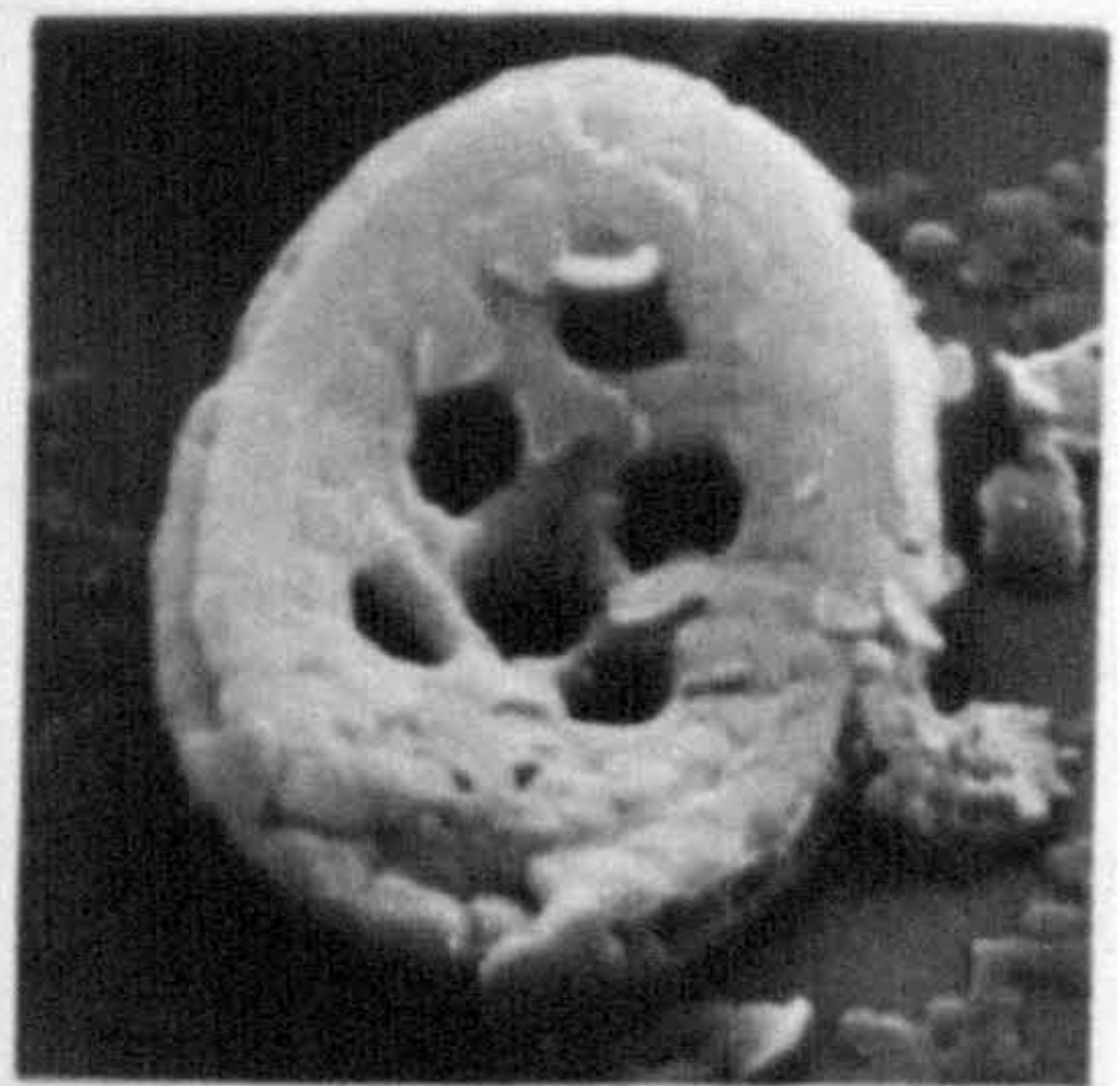
PLATE 4



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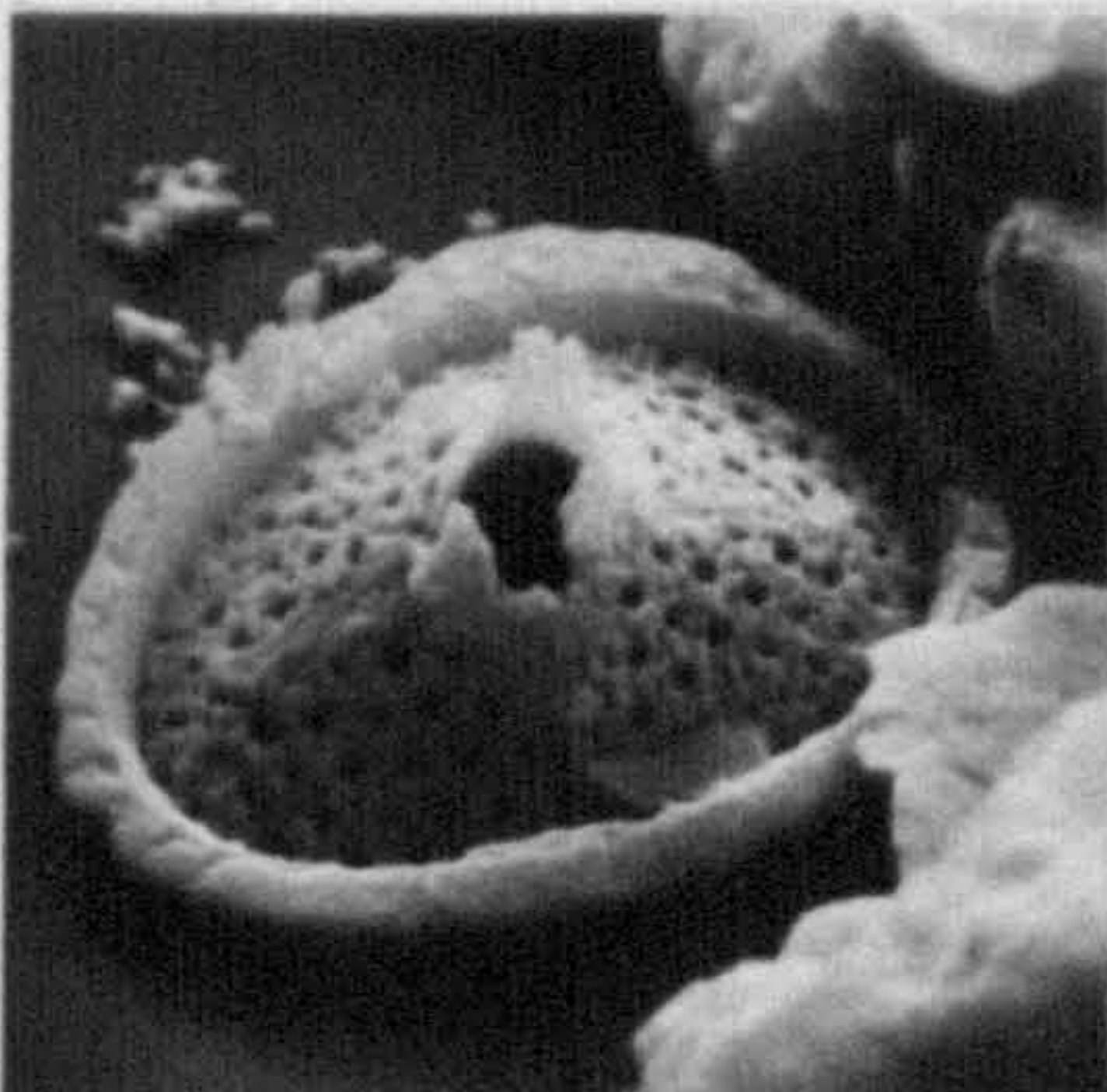
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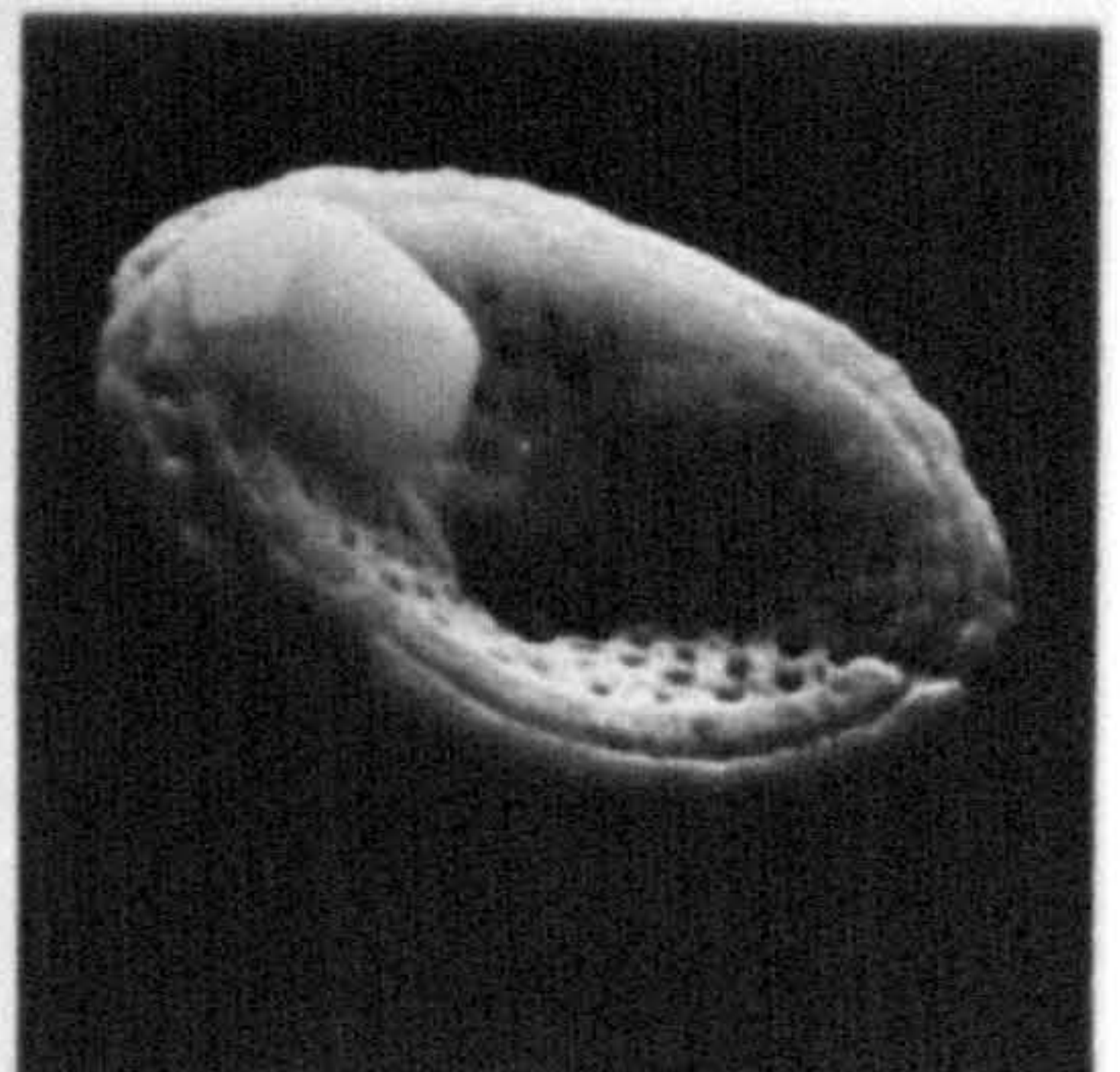
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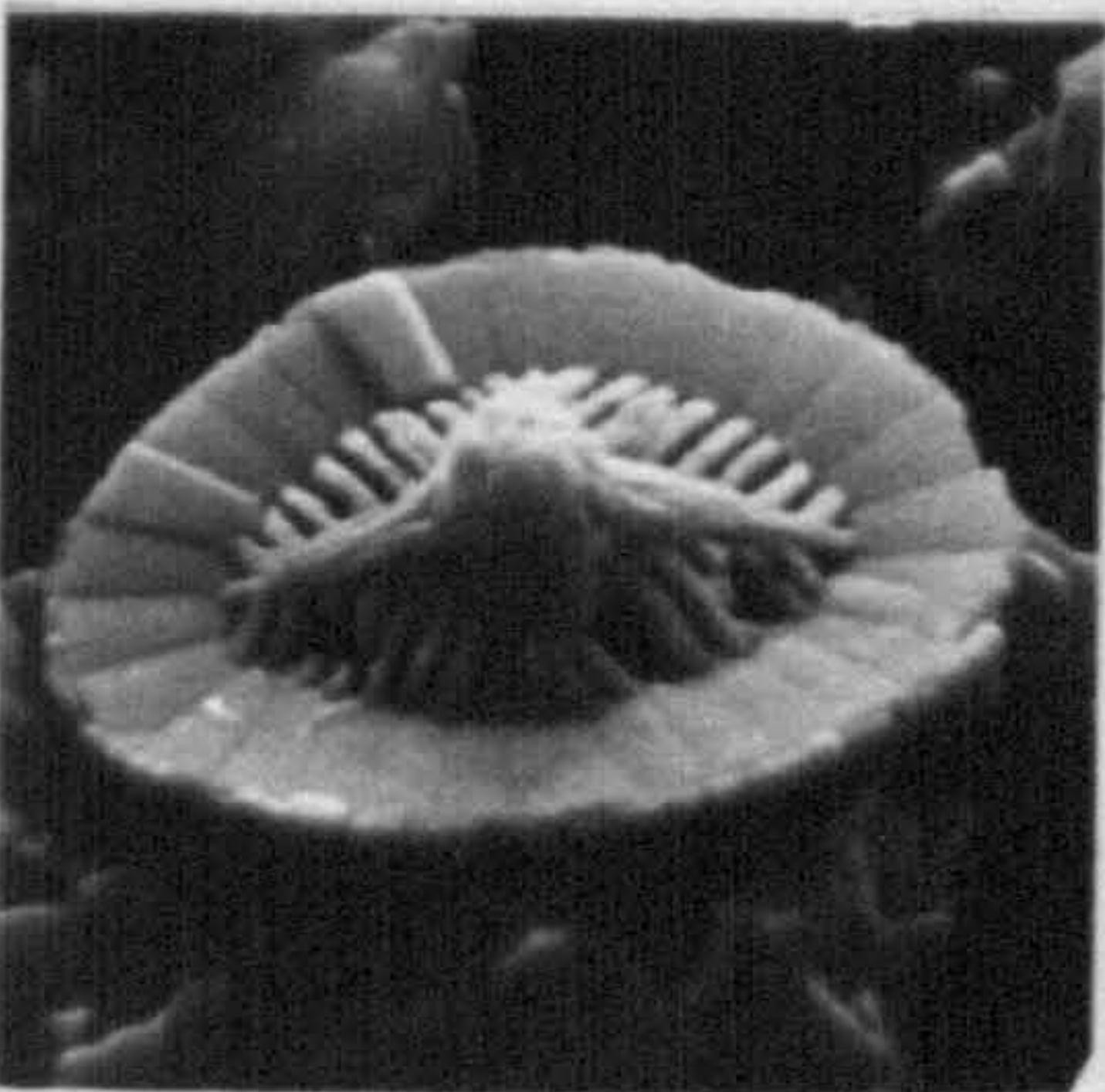
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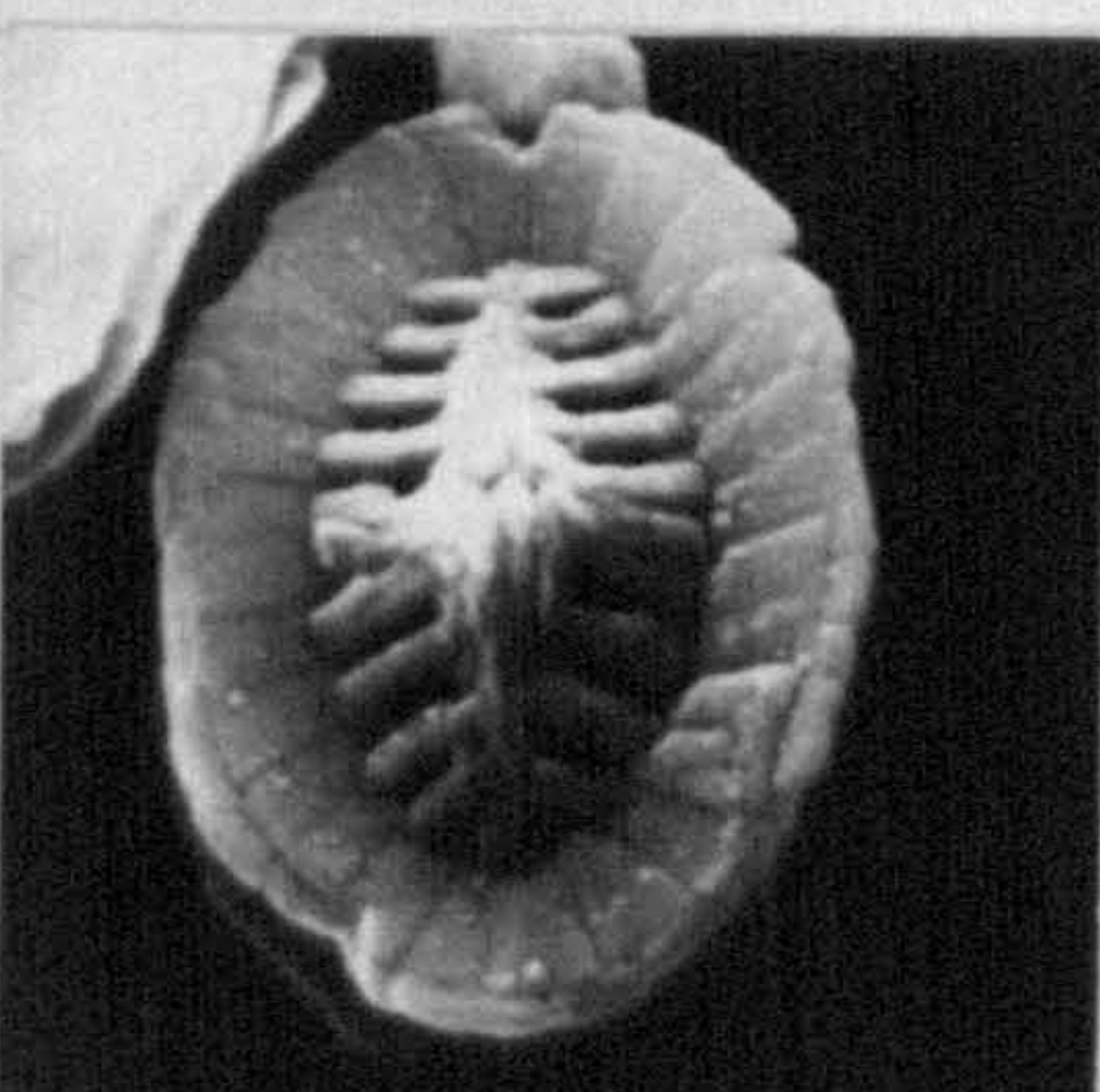
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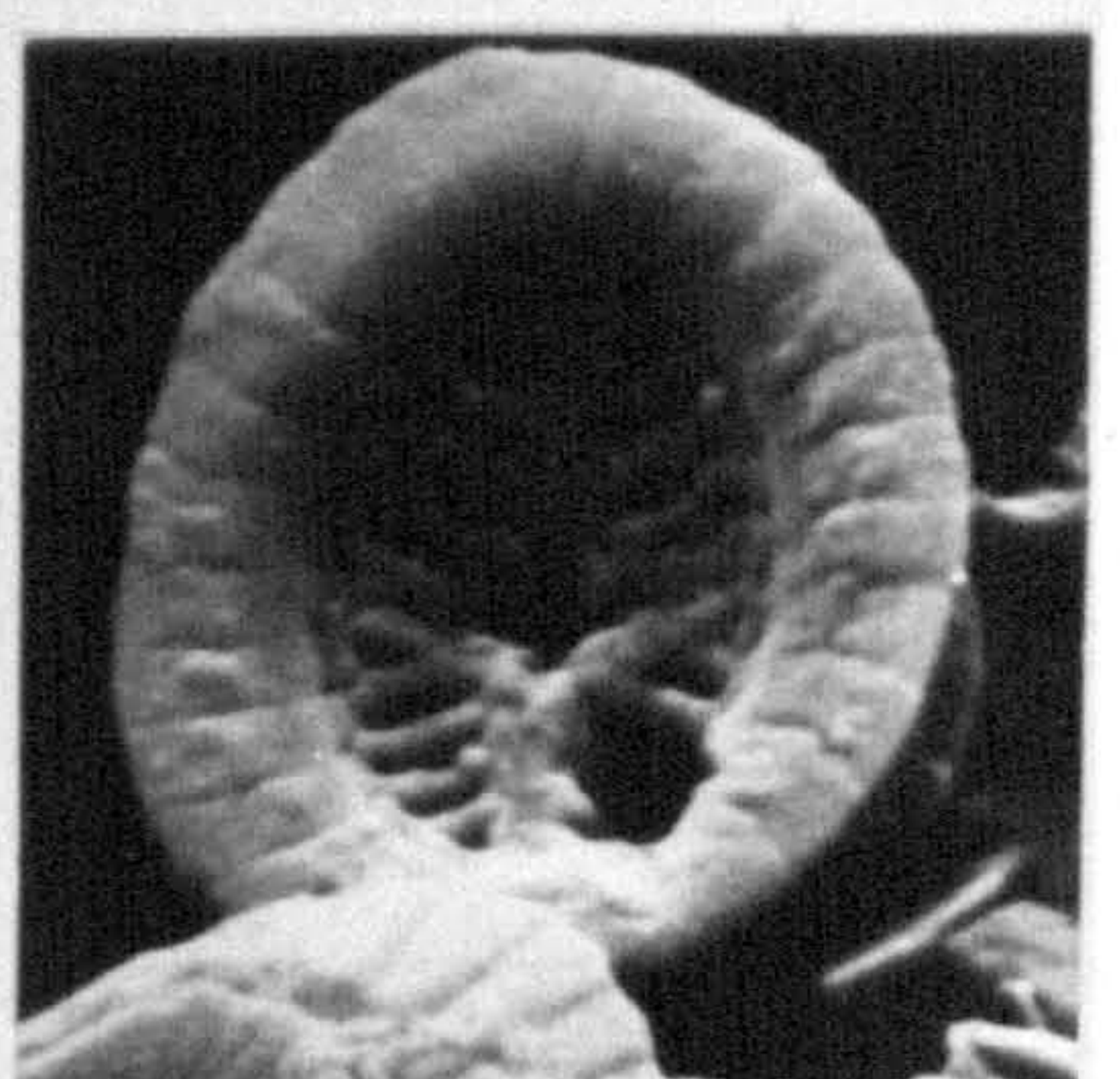
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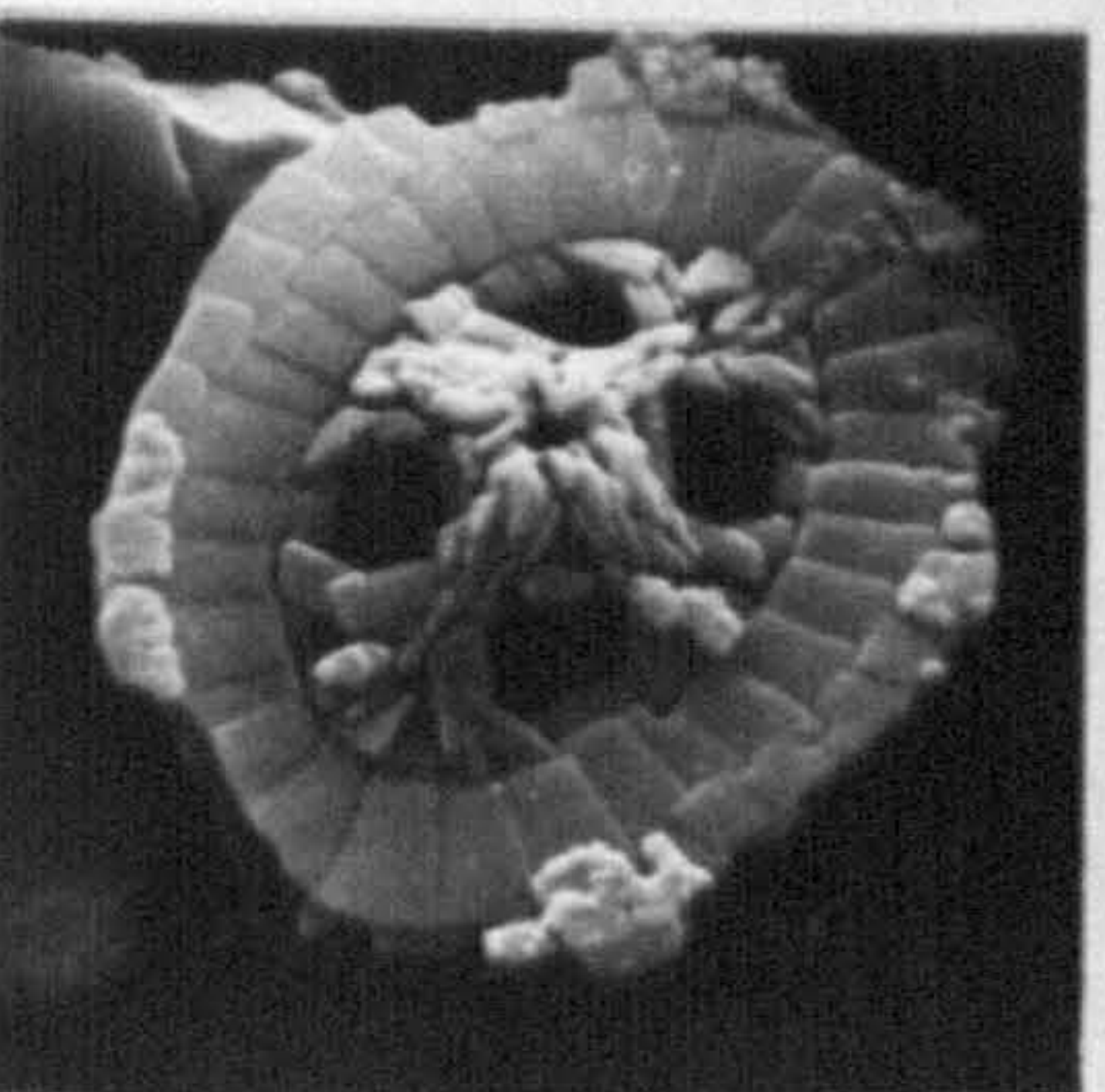
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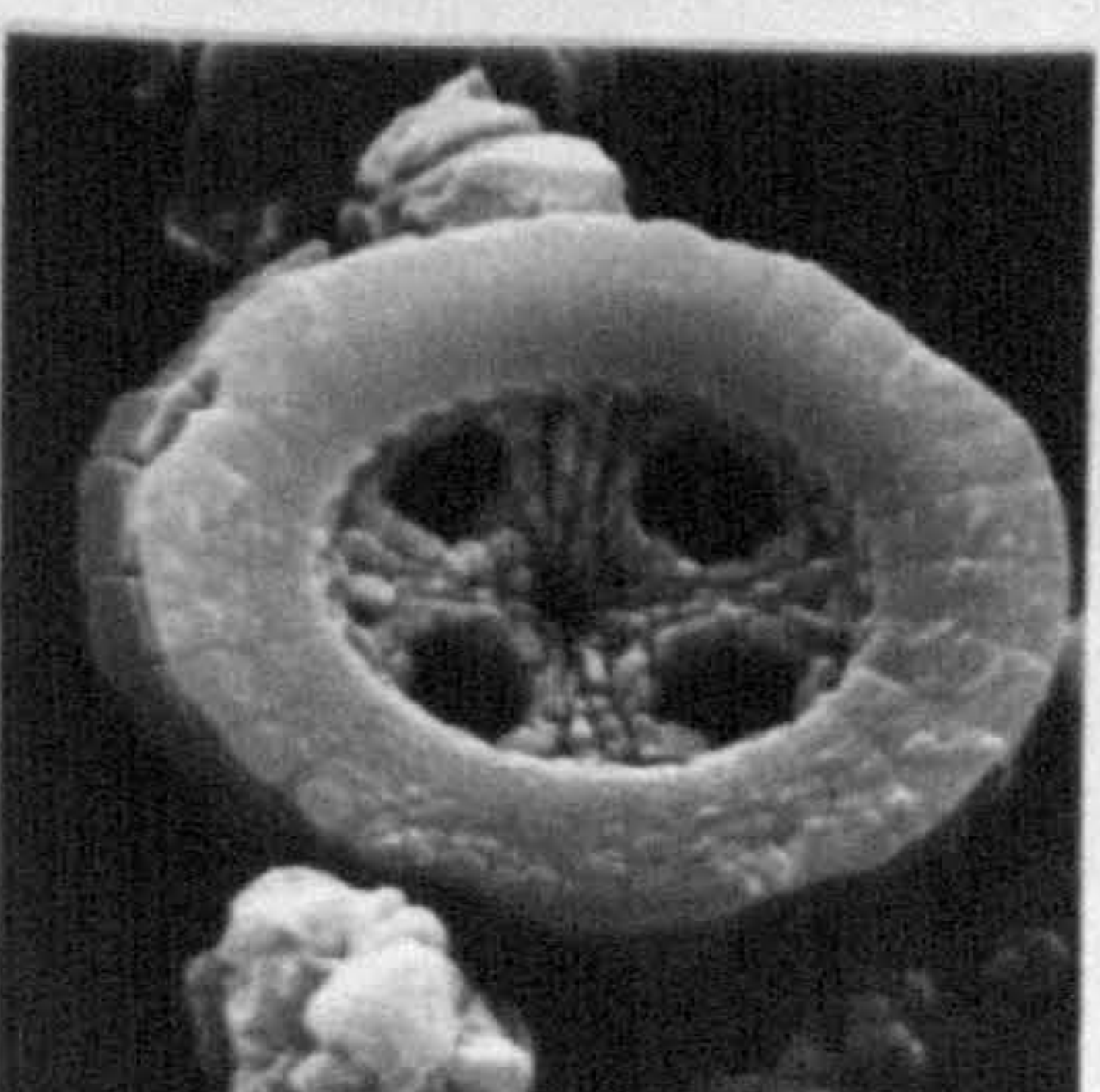
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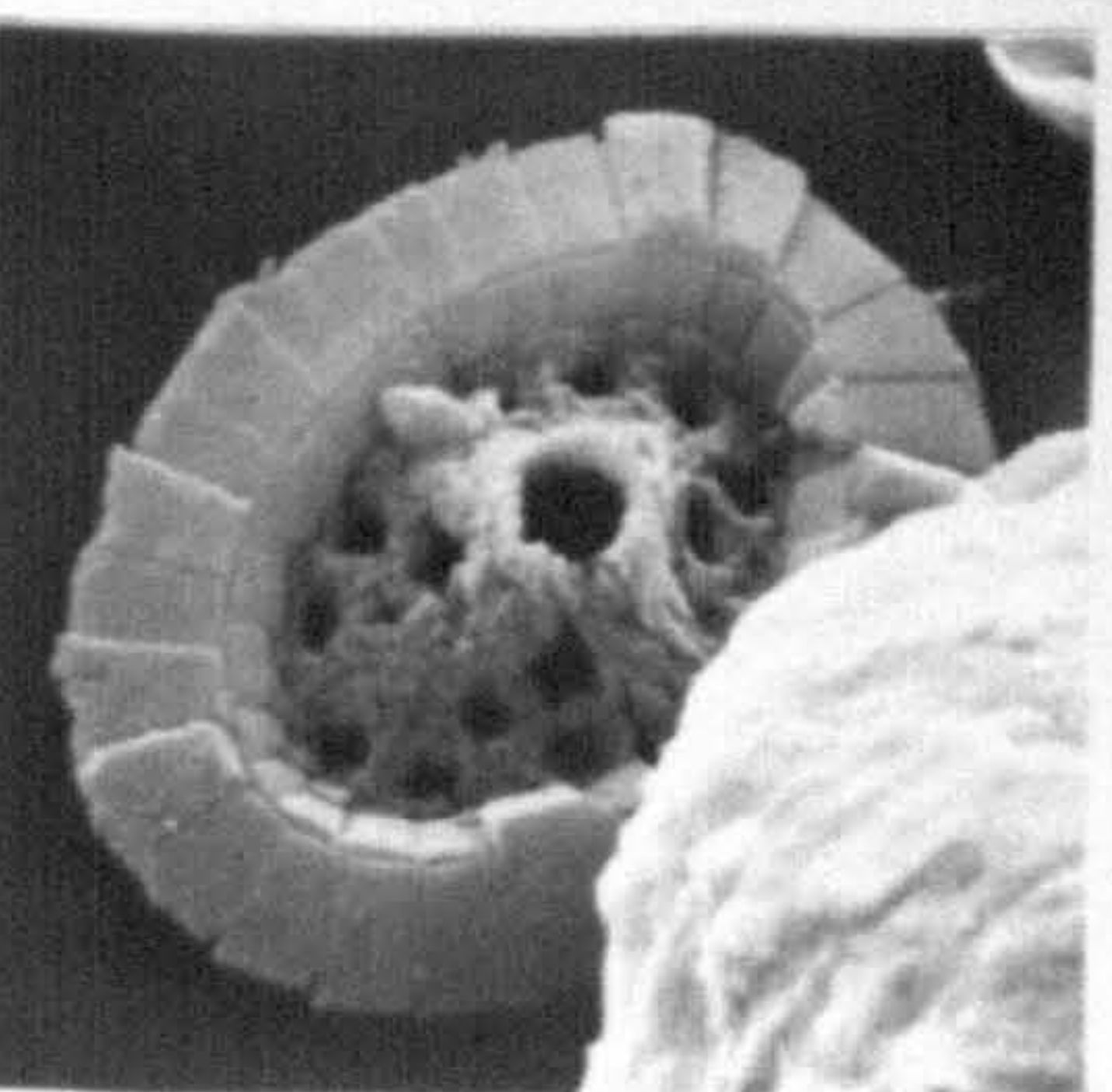
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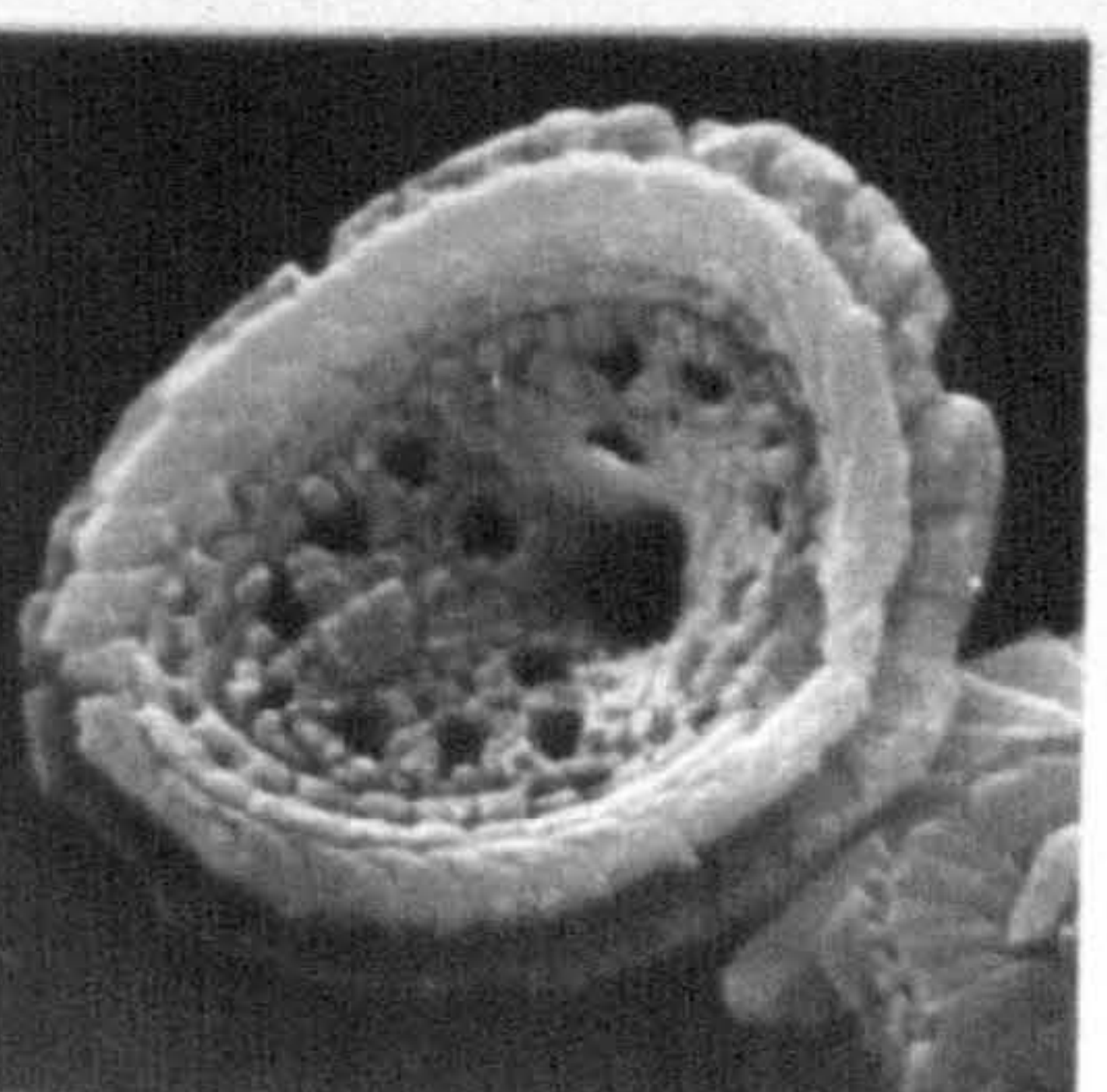
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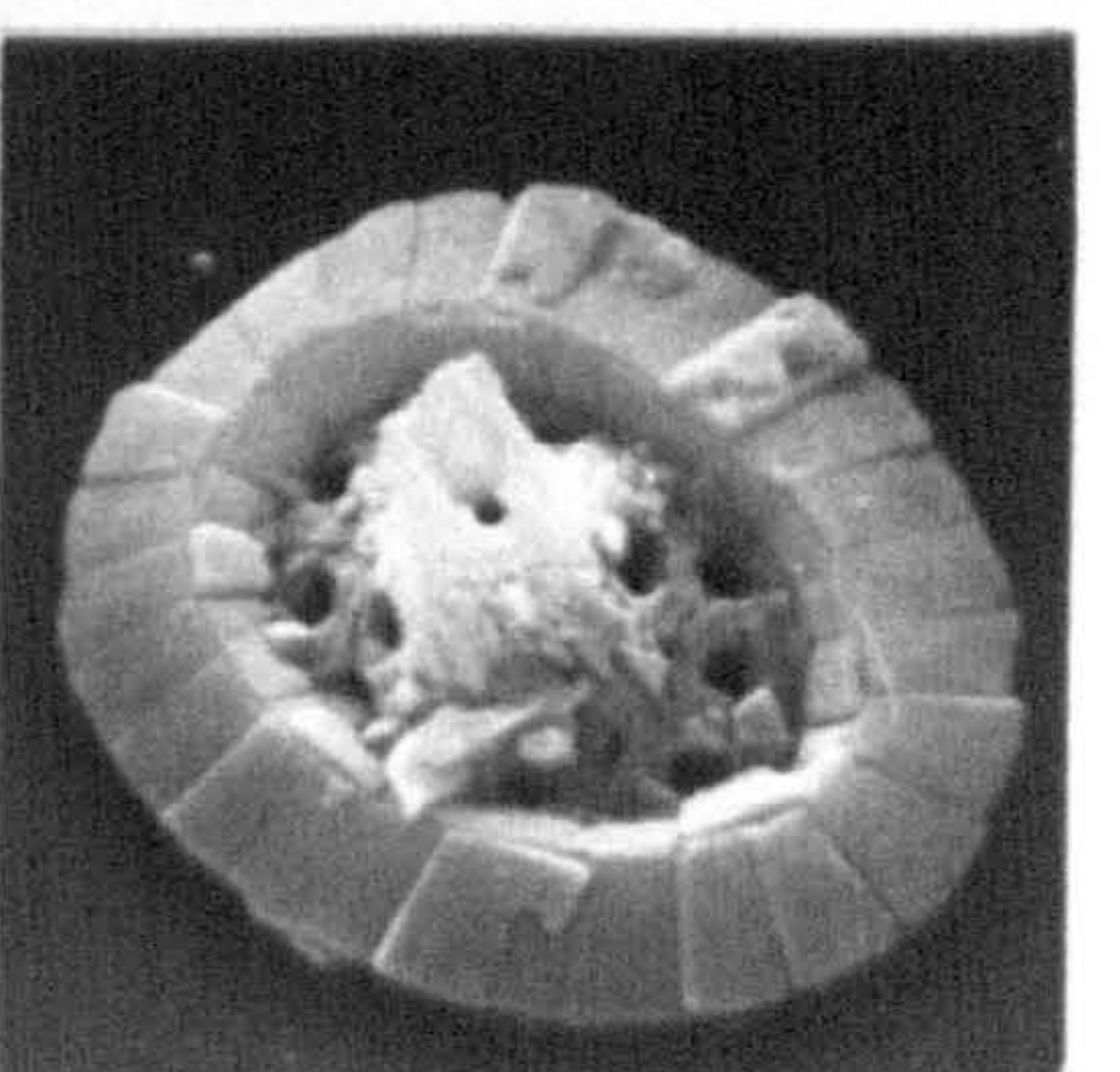
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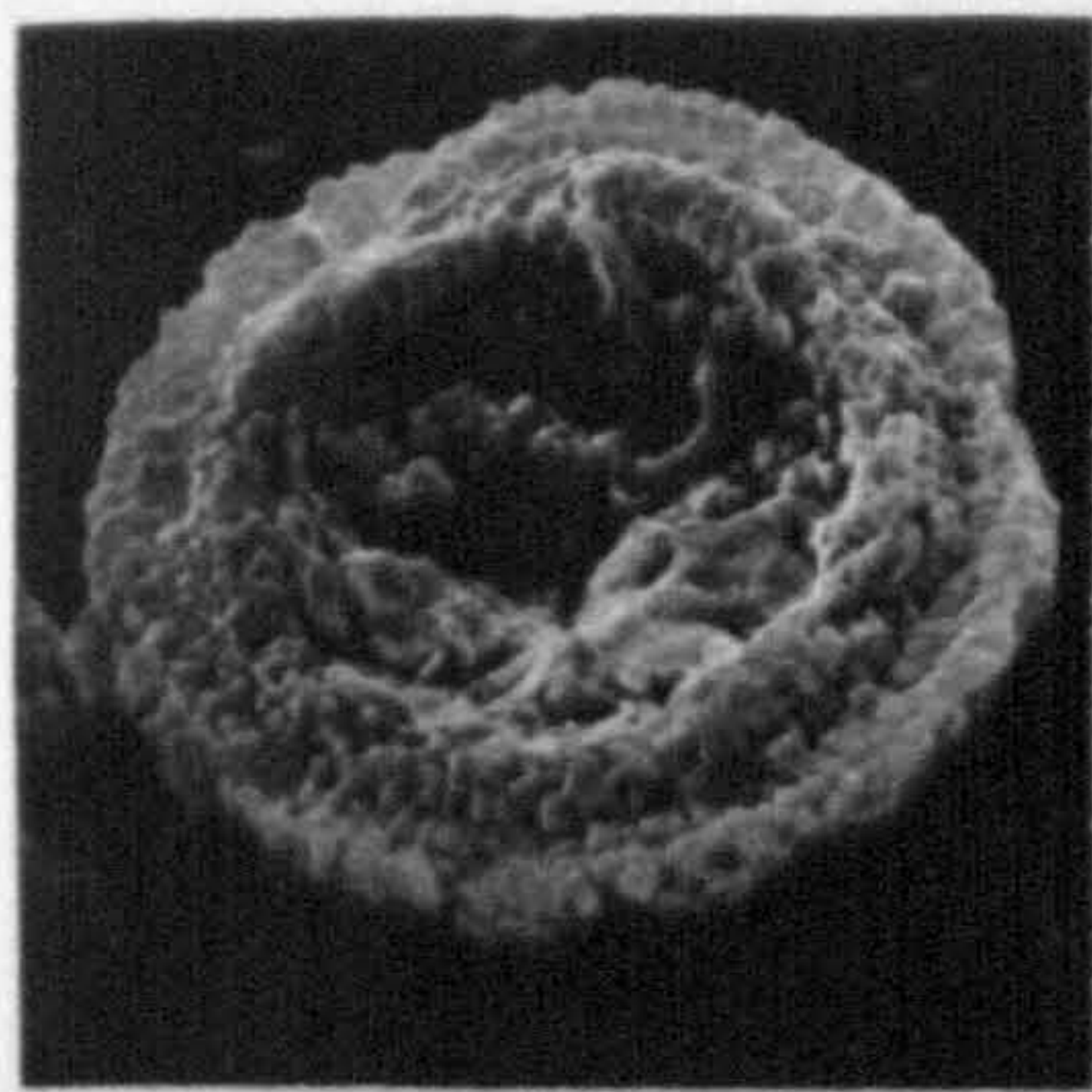


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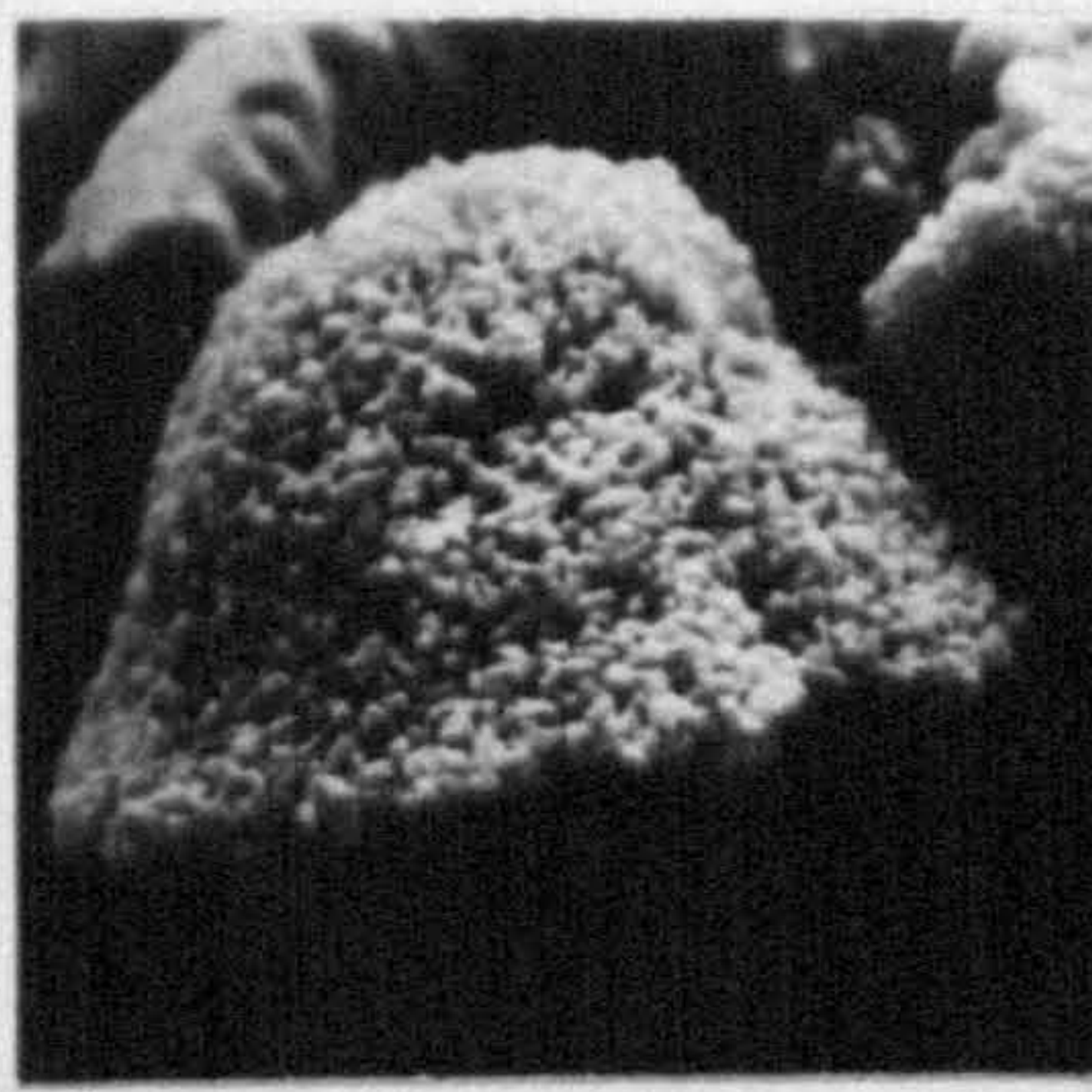
PLATE 5

- Fig. 1 Schizosphaerella punctulata DEFLANDRE & DANGEARD, Proximal side,
x 2,200, Toarcian, Brenha Rd., Neg. no. UCL-61-10.
- Fig. 2 Schizosphaerella punctulata DEFLANDRE & DANGEARD, Side view,
x 1,500, Toarcian, Brenha Rd., Neg. no. UCL-67-18.
- Fig. 3 Discorhabdus ignotus (GORKA), Proximal side,
x 8,000, Lower Pliensbachian, Brenha Rd., Neg. no. UCL-56-8.
- Fig. 4 Discorhabdus ignotus (GORKA), Proximal side,
x 6,400, Toarcian, Brenha Rd., Neg. no. UCL-65-19.
- Fig. 5 Discorhabdus ignotus (GORKA), Proximal side,
x 7,300, Toarcian, Brenha Rd., Neg. no. UCL-66-11.
- Fig. 6 Discorhabdus ignotus (GORKA), Proximal side,
x 5,800, Lower Bajocian, Brenha Rd., Neg. no. UCL-90-18.
- Fig. 7 Discorhabdus biperforatus ROOD, HAY & BARNARD, Distal side,
x 5,500, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL- 509-18.
- Fig. 8 Discorhabdus biperforatus ROOD, HAY & BARNARD, Distal side,
x 5,600, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-513-11.
- Fig. 9 Discorhabdus ignotus (GORKA), Proximal side,
x 10,500, Toarcian, Brenha Rd., Neg. no. UCL-65-25.
- Fig. 10 Discorhabdus sp. Distal side,
x 6,500, Bathonian, Cap Mondego, Neg. no. UCL-374-8.
- Fig. 11 Discorhabdus sp. Distal side,
x 6,900, Bathonian, Cap Mondego, Neg. no. UCL-374-16.
- Fig. 12 Discorhabdus ignotus (GORKA), Distal side,
x 8,500, Toarcian, Brenha Rd., Neg. no. UCL-60-22.
- Fig. 13 Parhabdolithus marthae DEFLANDRE, Side view,
x 5,600, Upper Sinemurian, Brenha Rd., Neg. no. UCL- 56 -29.
- Fig. 14 Podorhabdus rahla NOEL, Side view,
x 4,100, Upper Callovian, Skye, Neg. no. UCL-446-28.
- Fig. 15 Discorhabdus jungi NOEL, Side view,
x 5,400, Upper Callovian, Skye, Neg. no. UCL- 446-22.

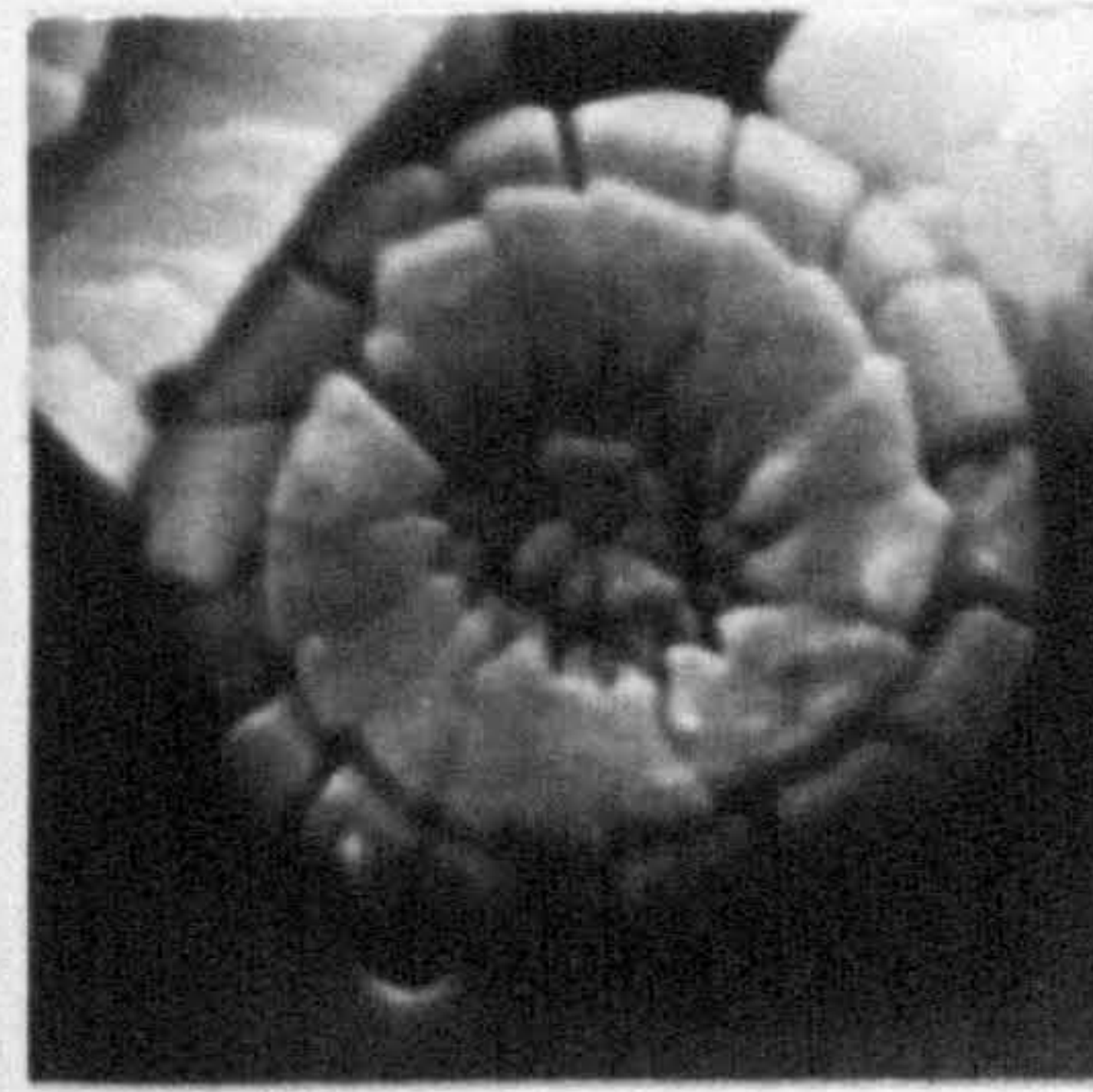
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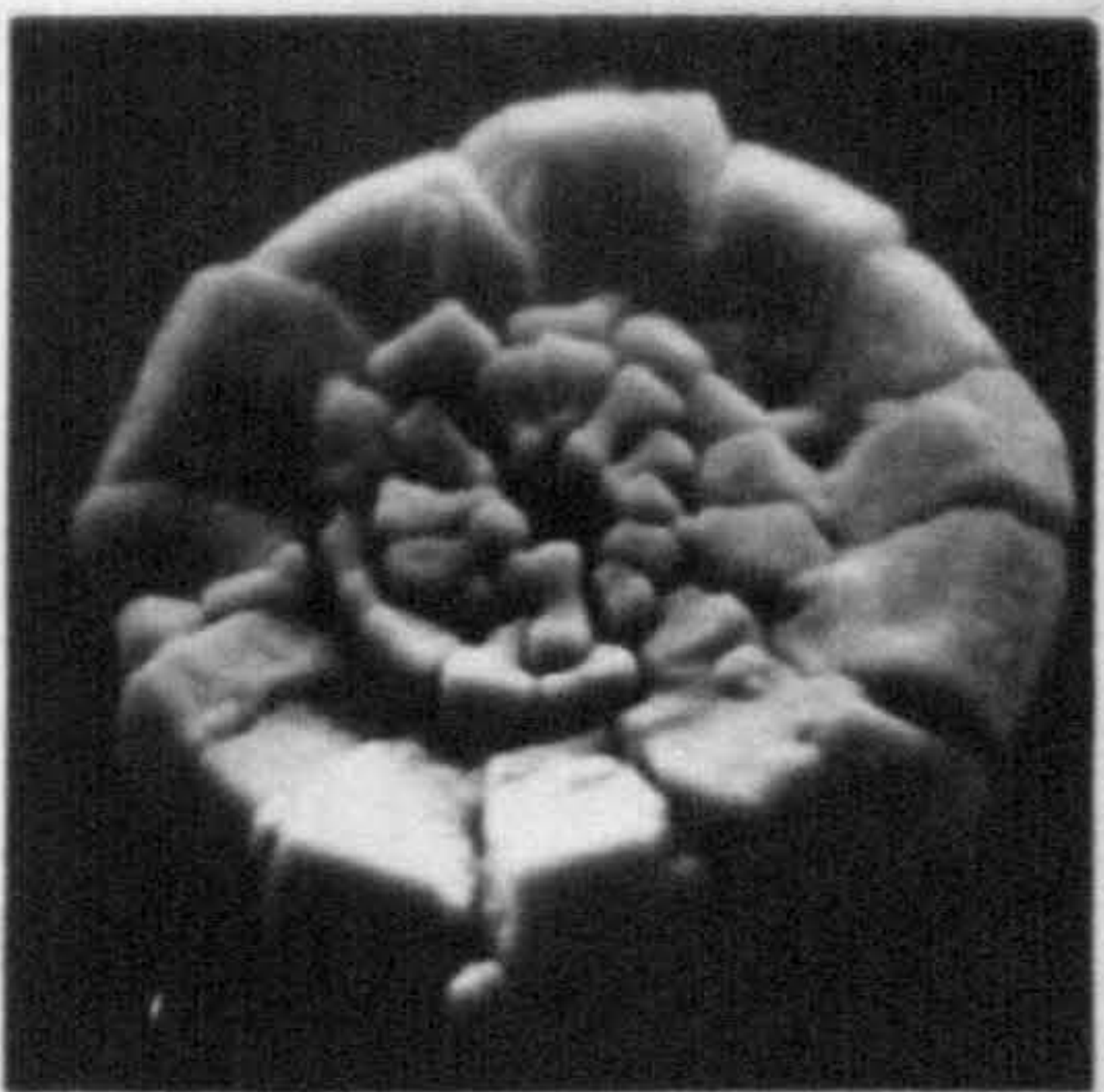
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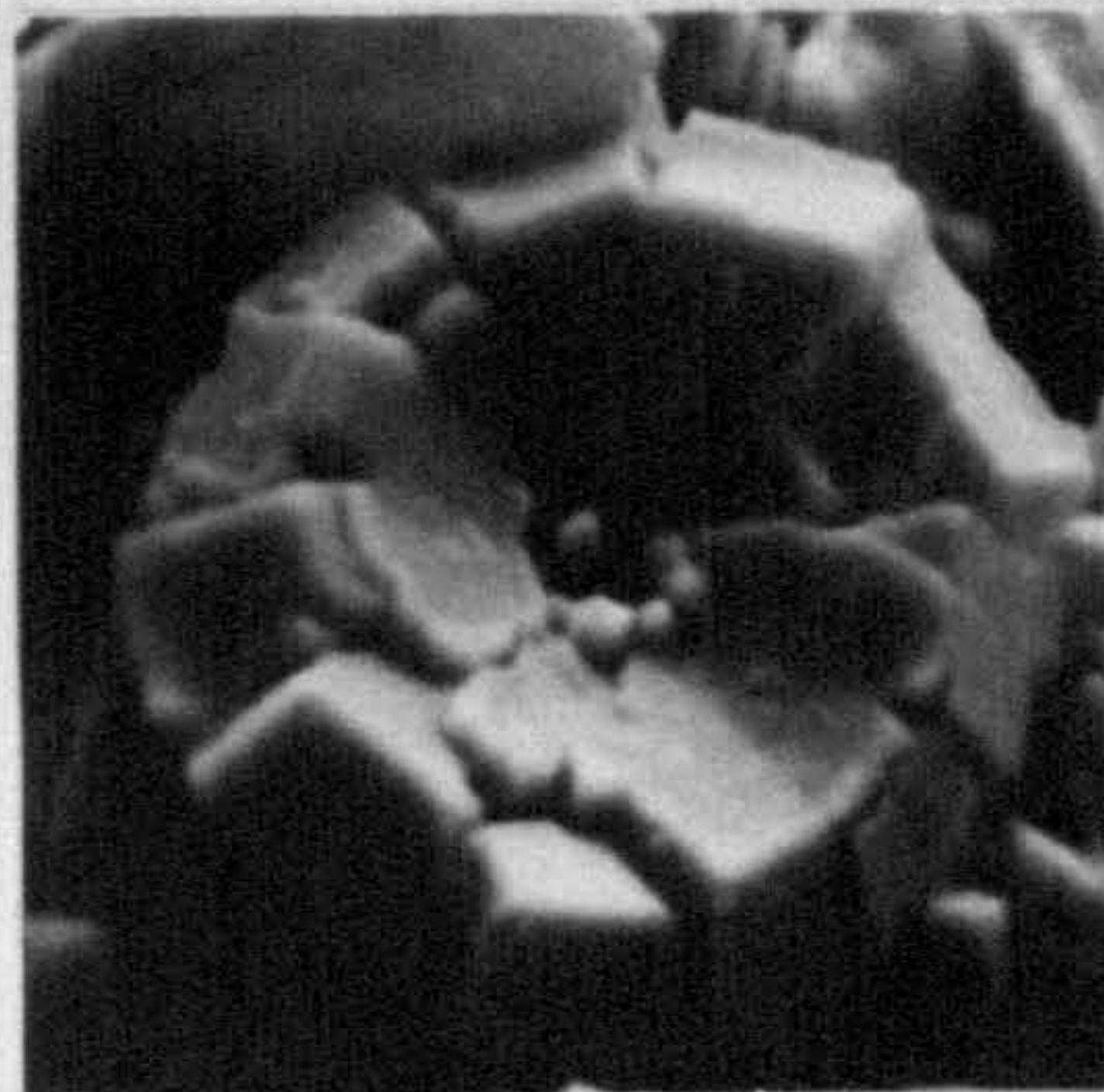
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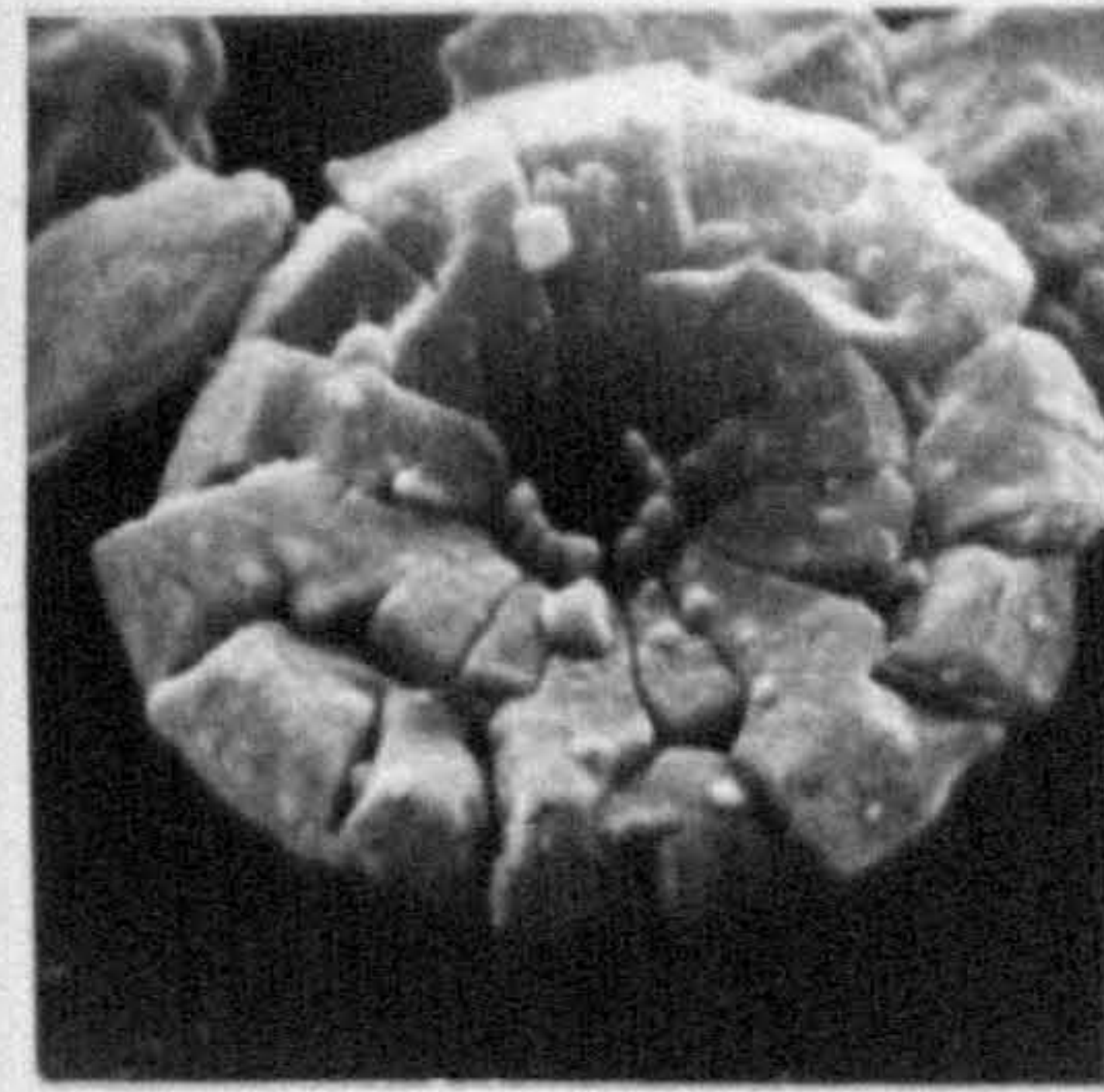
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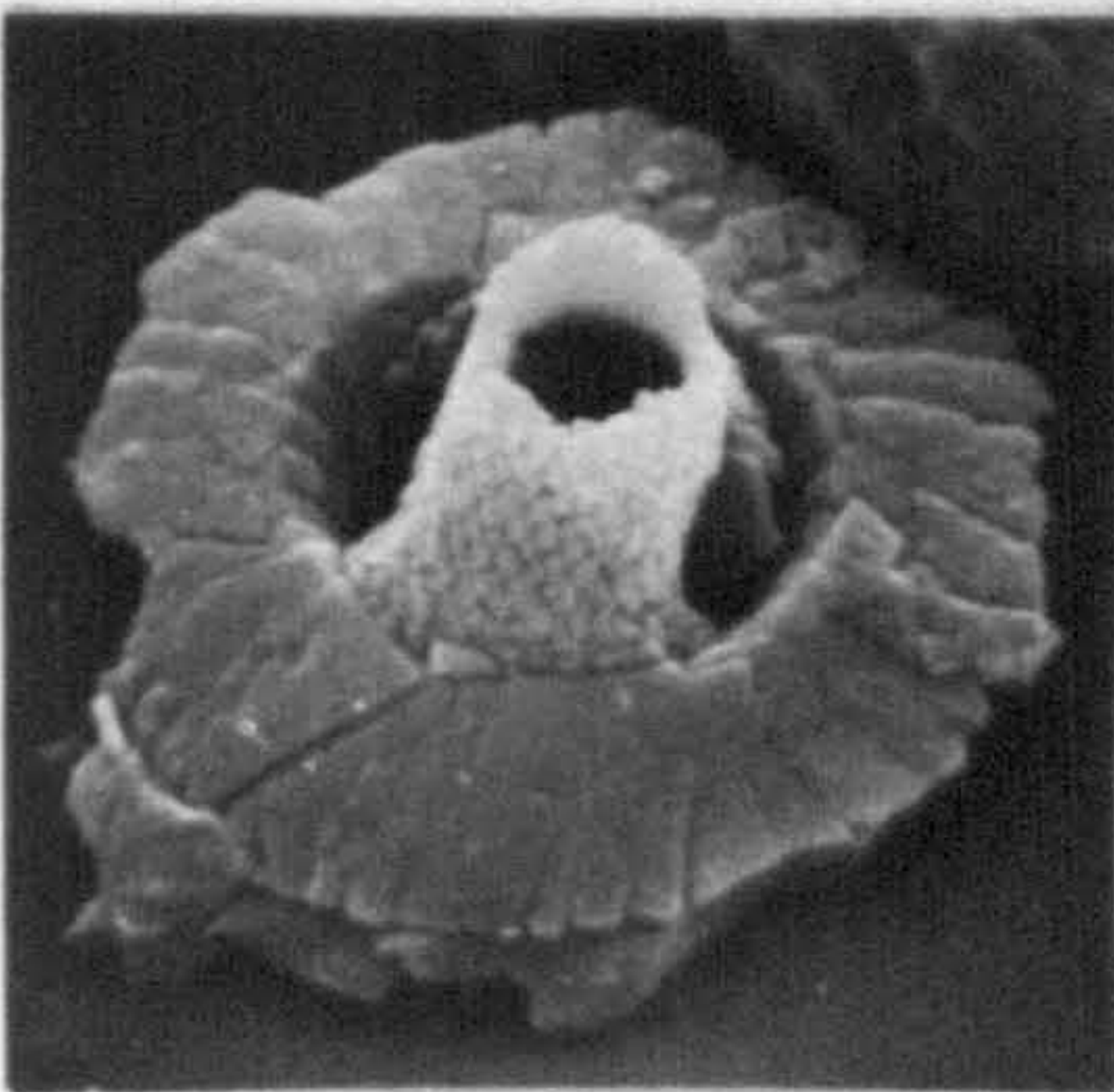
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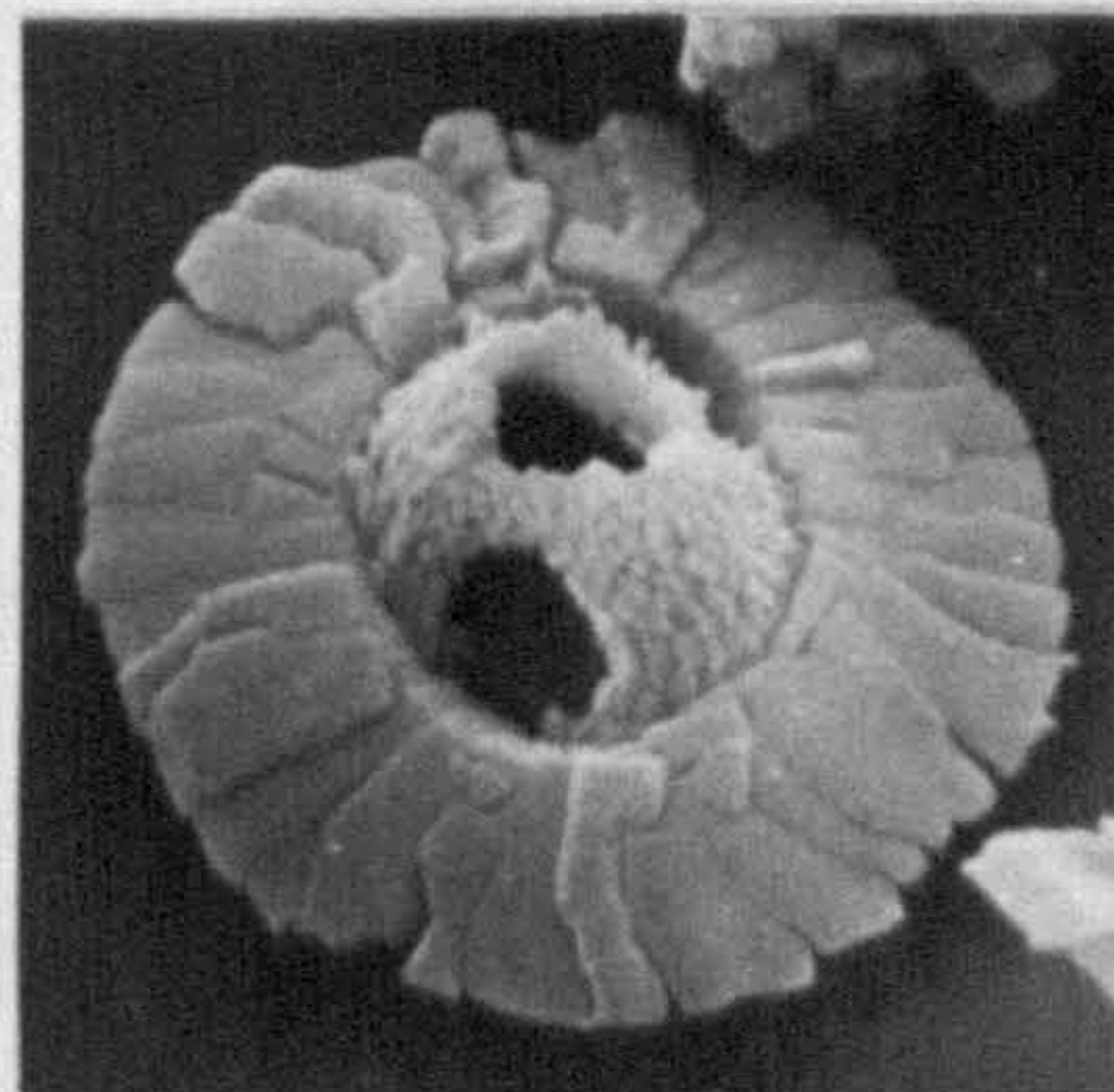
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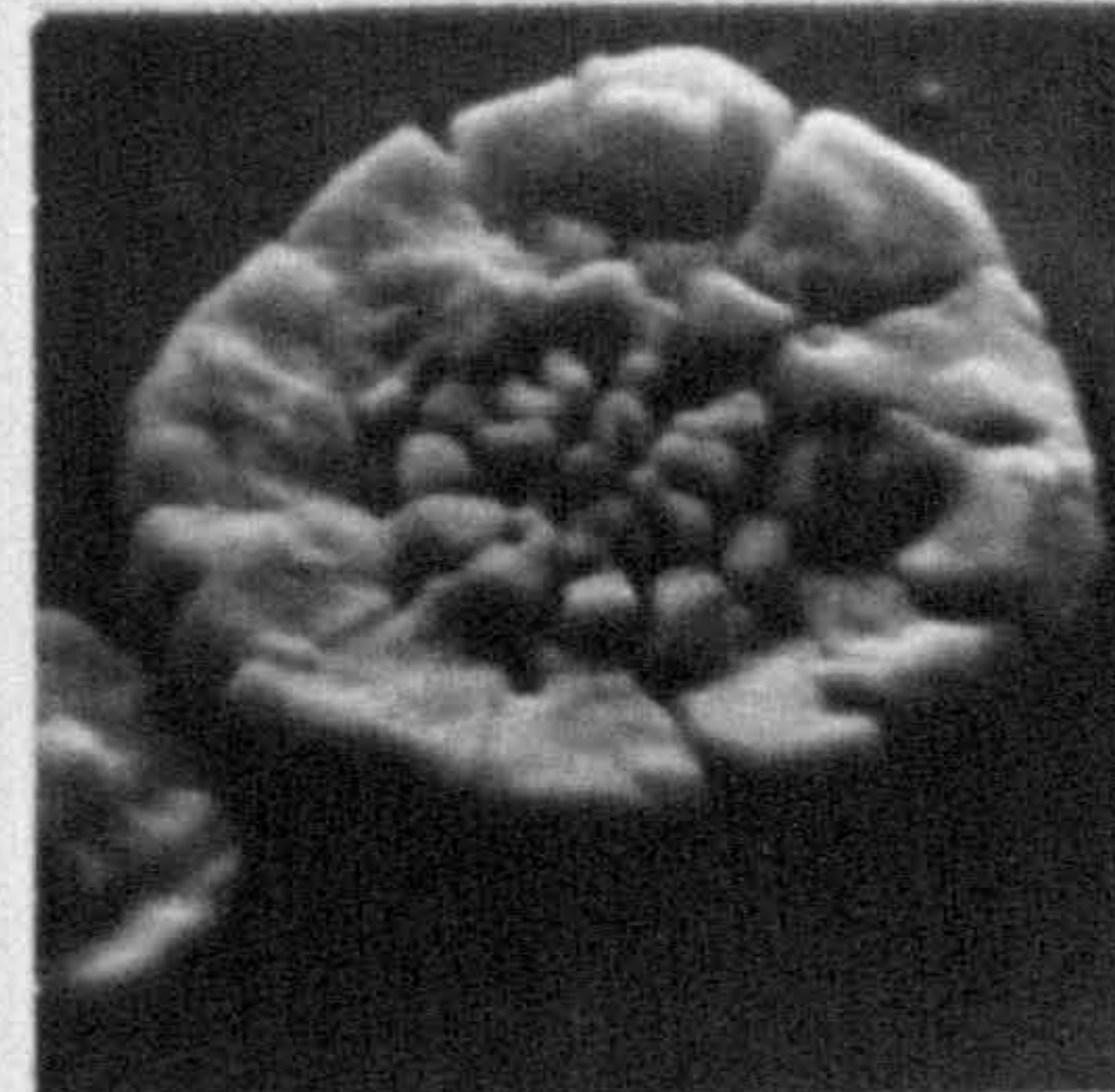
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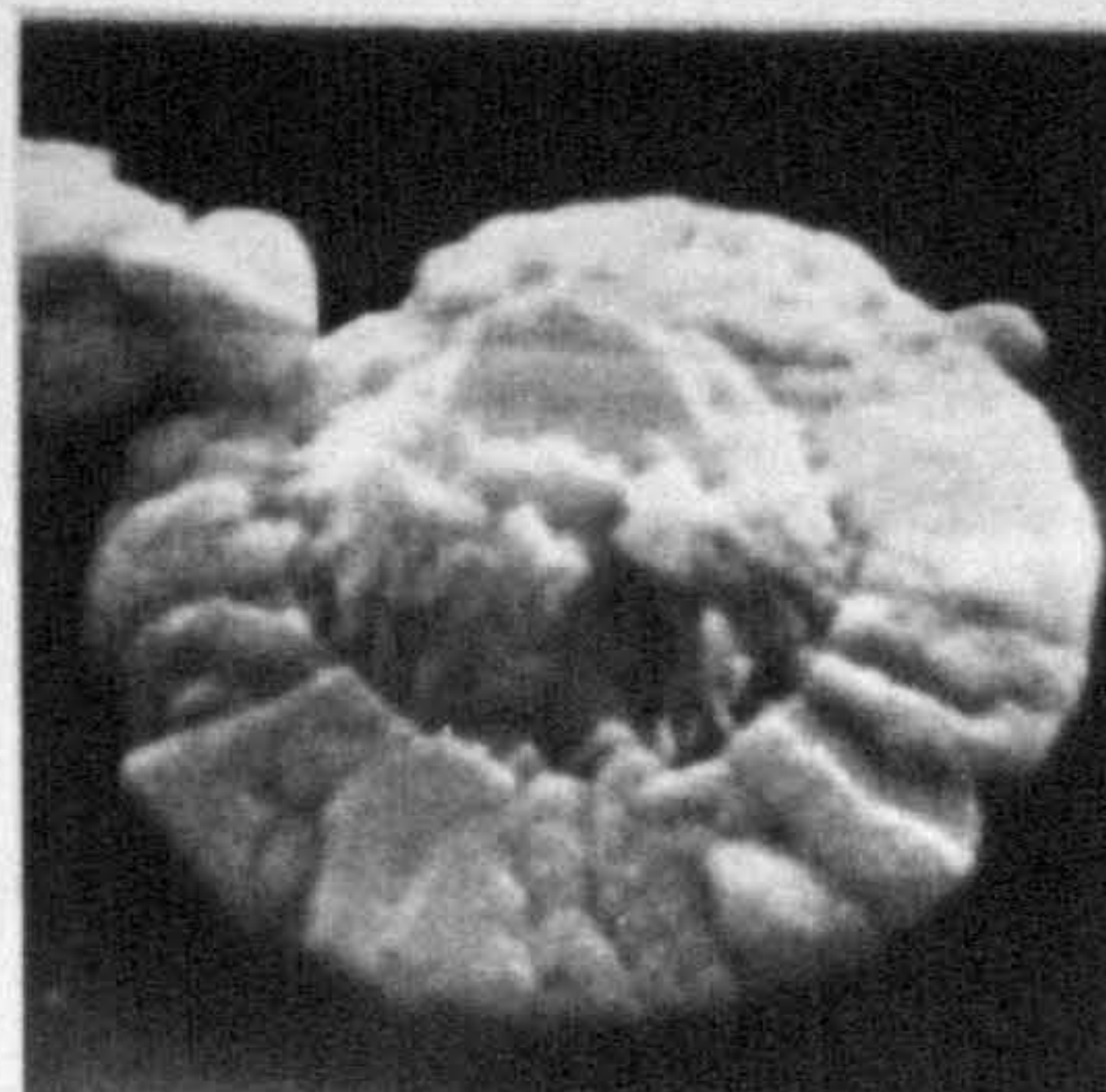
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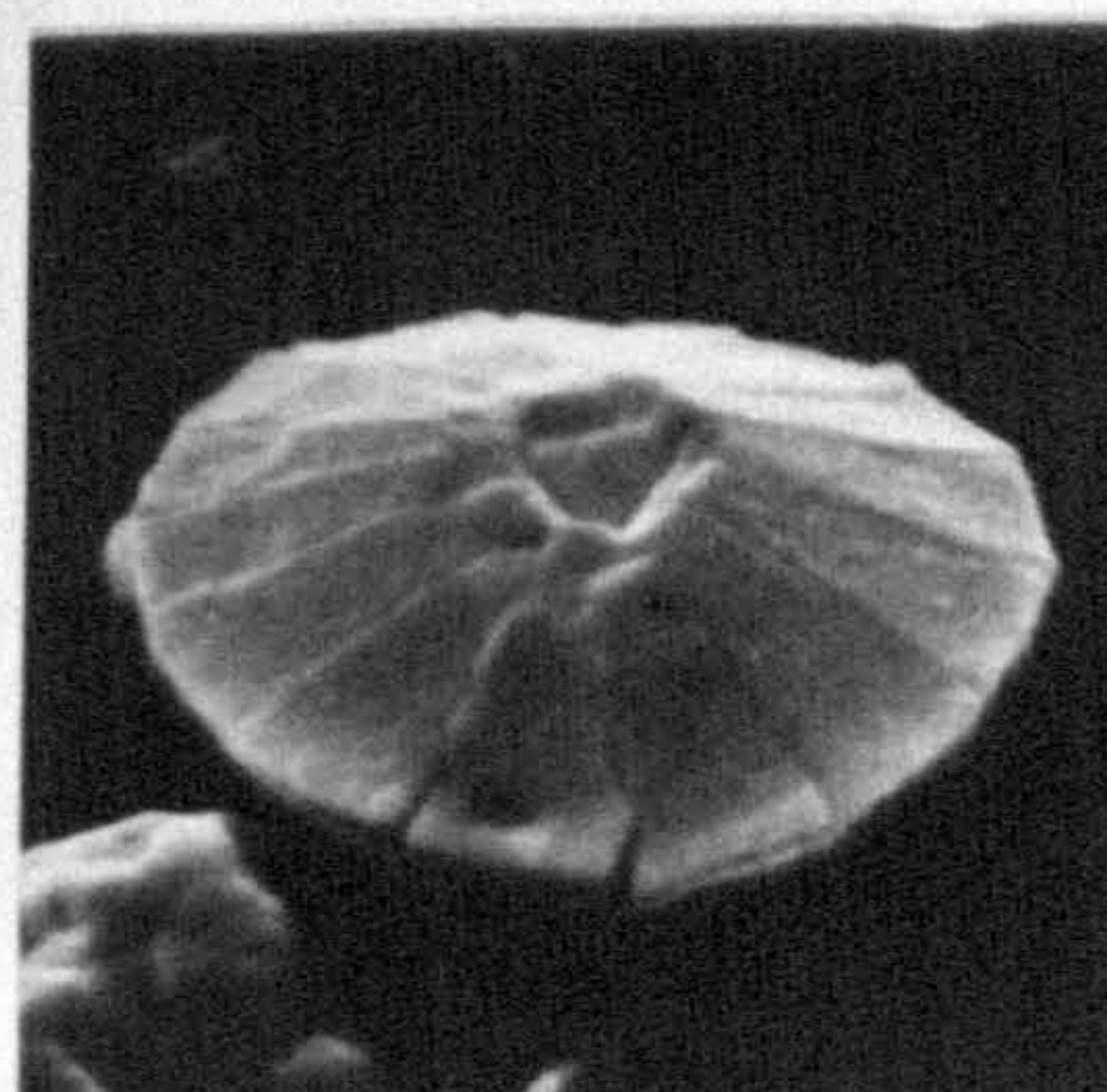
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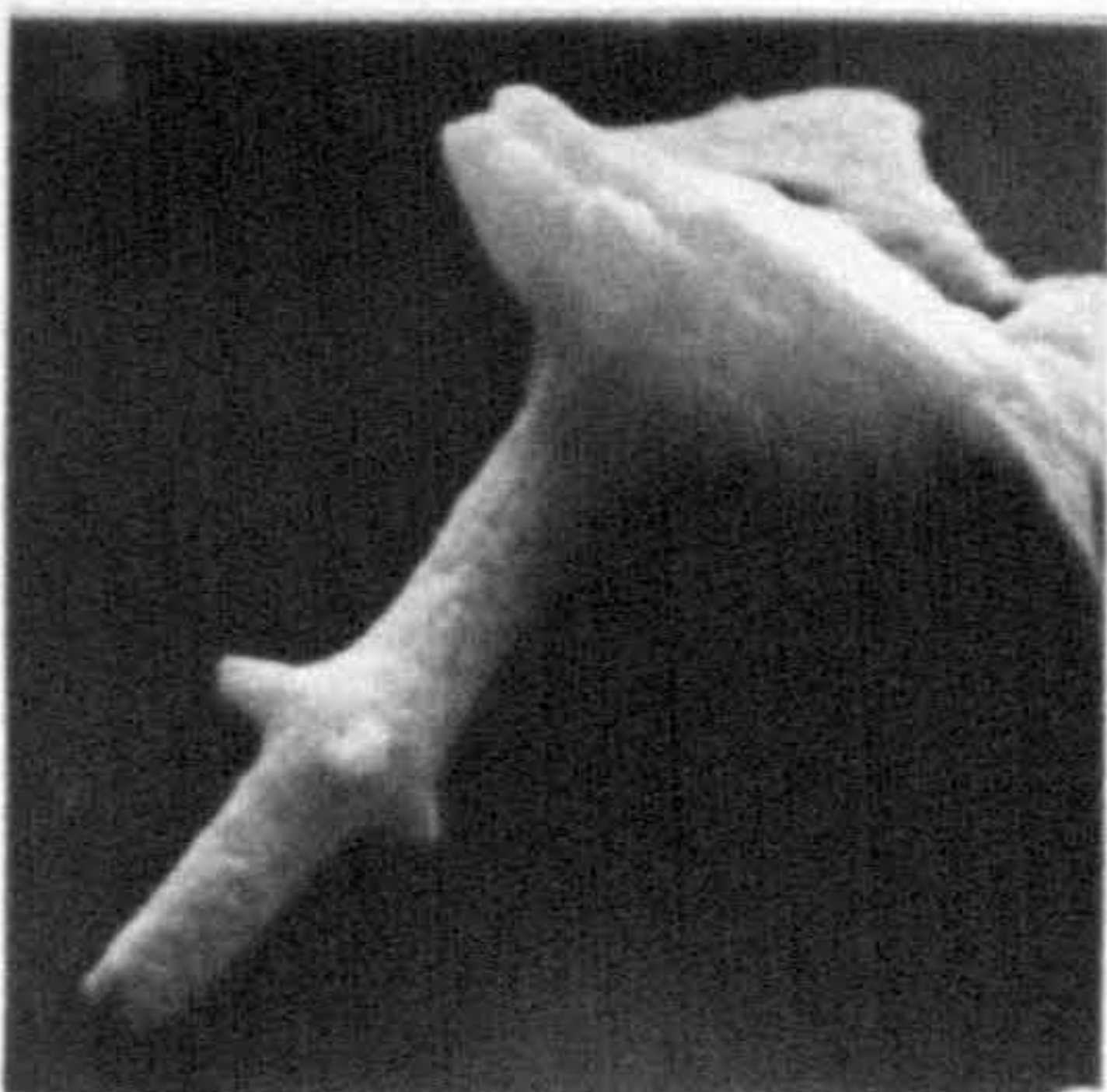
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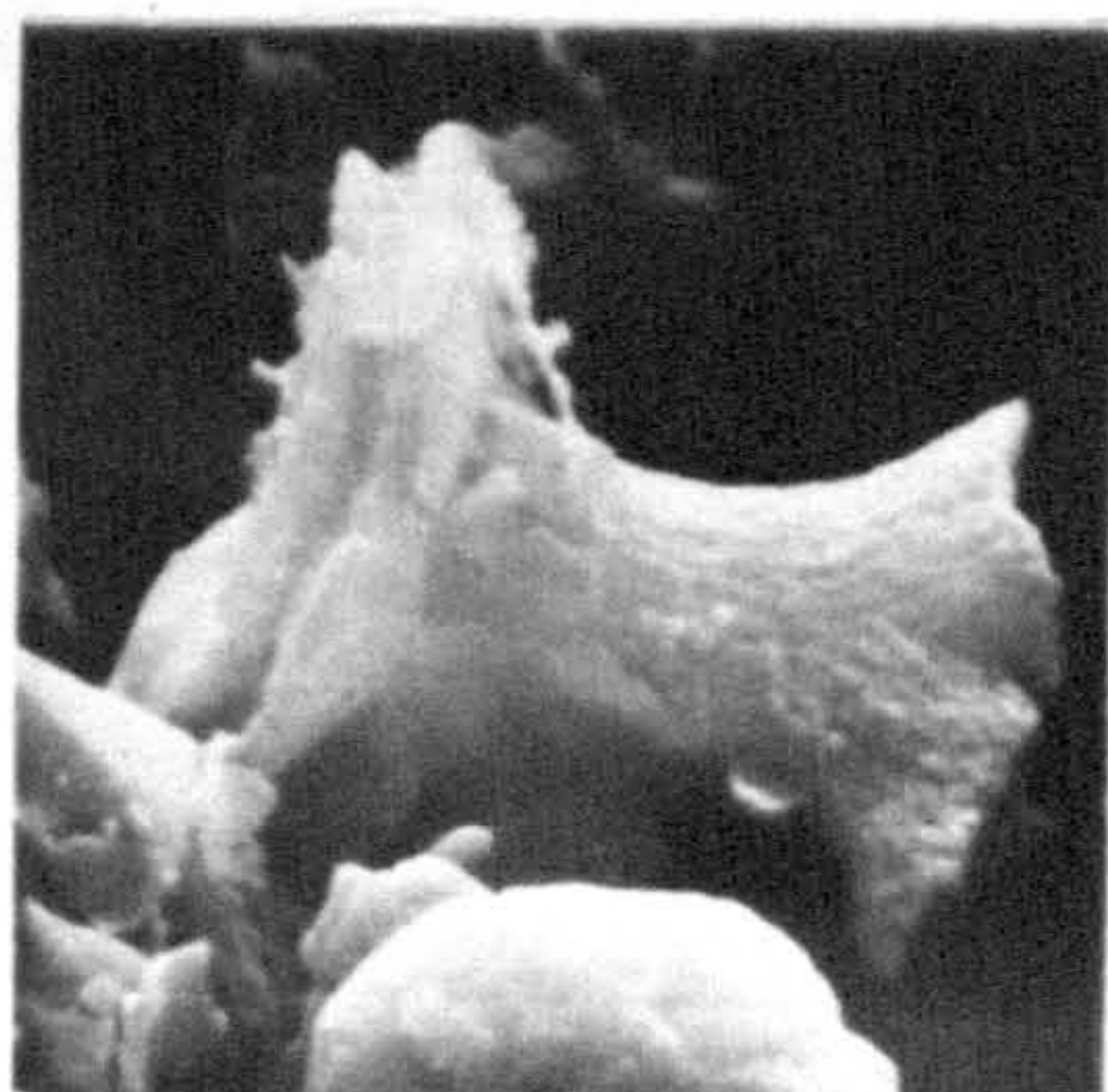
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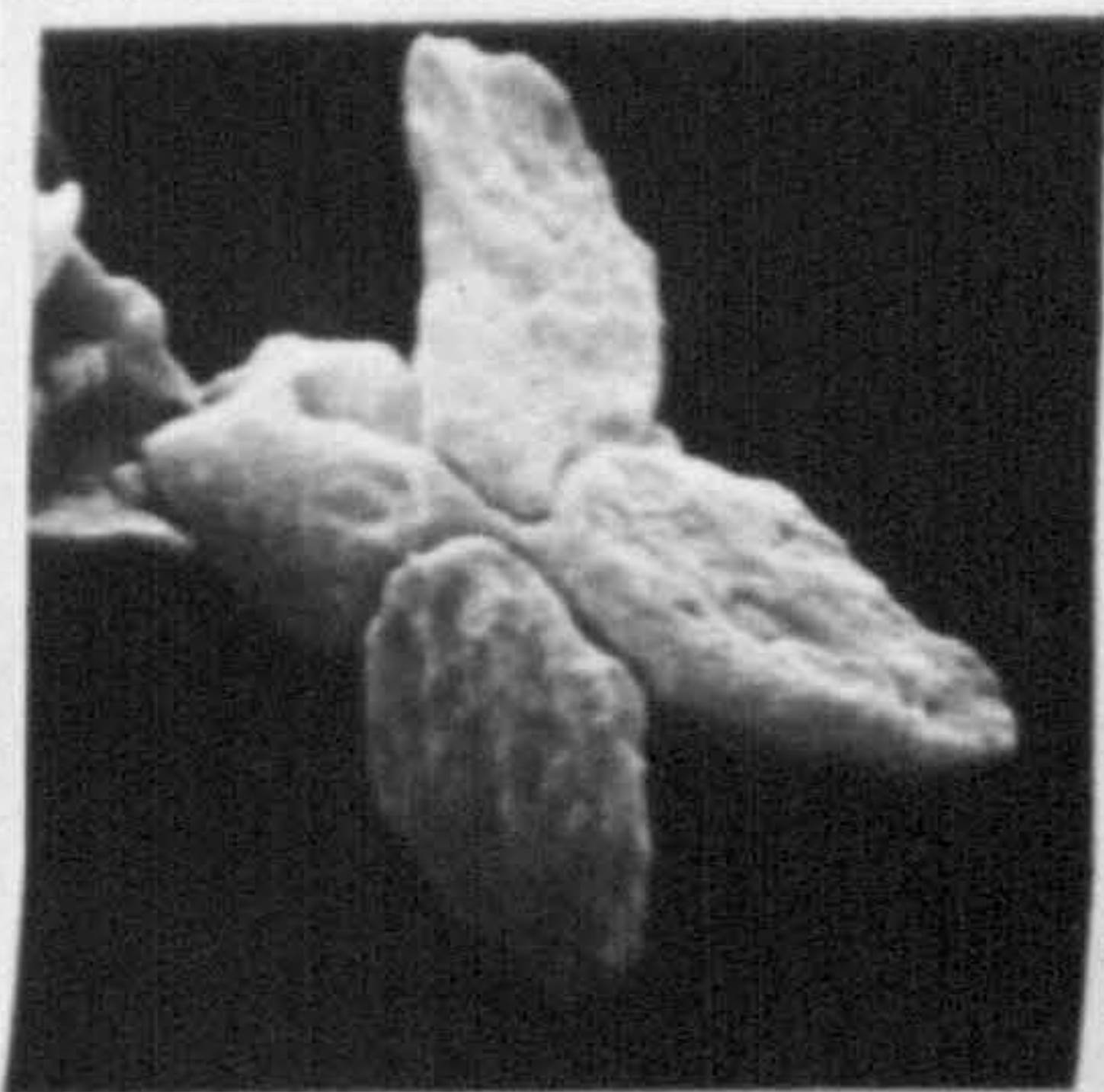


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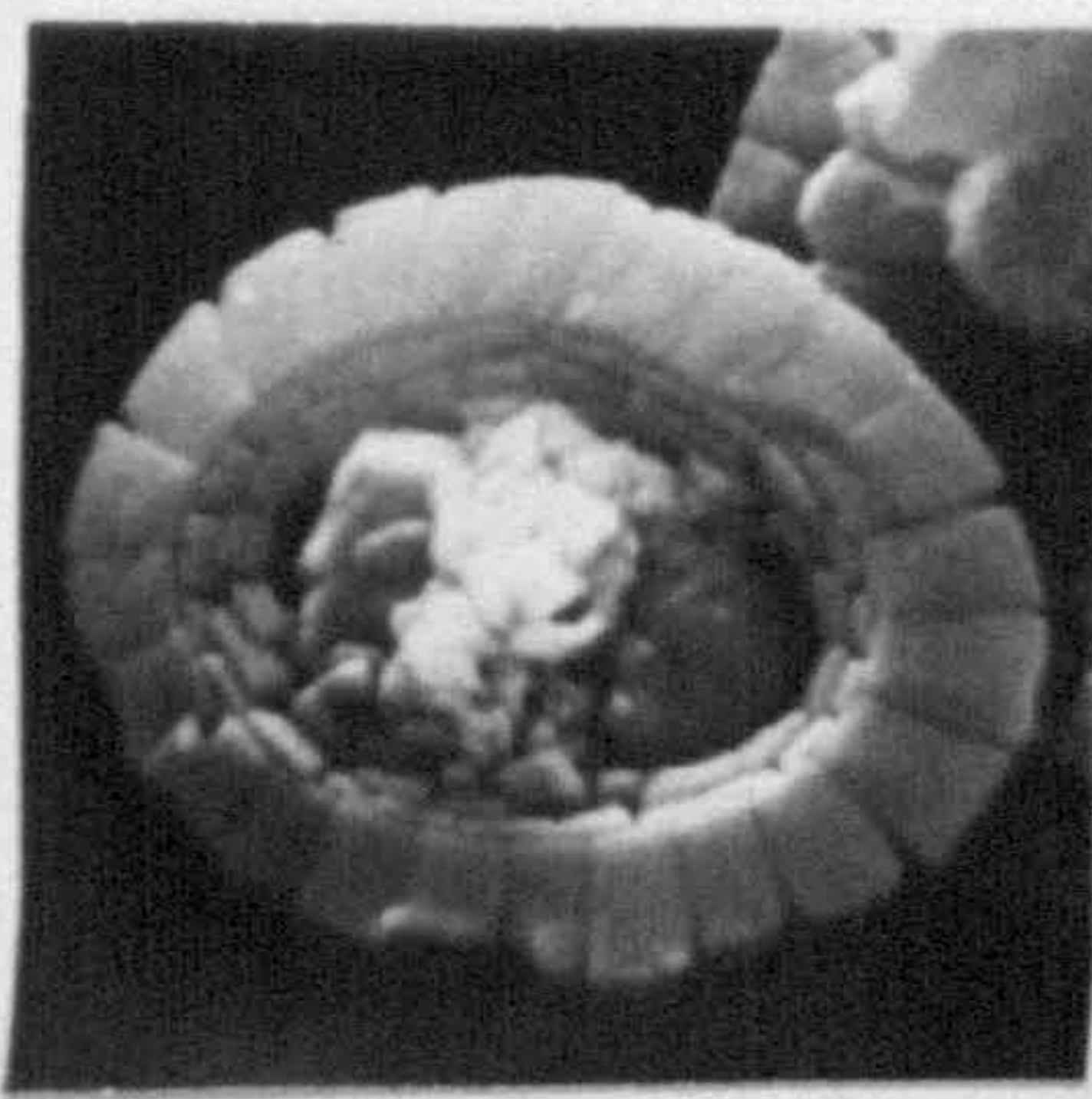
PLATE 6

- Fig. 1 Tetralithus gothicus DEFLANDRE
x 6,200, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-542-24.
- Fig. 2 Hemipodorhabdus gorkae (REINHARDT), Distal side,
x 6,000, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-637-26.
- Fig. 3 Hemipodorhabdus gorkae (REINHARDT), Proximal side,
x 6,000, Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-509-3.
- Fig. 4 Biscutum ellipticum (GORKA), Distal side,
x 7,200, Lias, Peniche, Neg. no. UCL-539-22.
- Fig. 5 Markalius inversus (DEFLANDRE), Proximal side,
x 3,500, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-588-22.
- Fig. 6 Diazomatolithus sp., Proximal side,
x 2,700, Bathonian, Brenha Rd., Neg. no. UCL-101-8.
- Fig. 7 Nannoconus steinmanni KAMPTNER, Side view,
x 2,700, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-588-14.
- Fig. 8 Nannoconus steinmanni KAMPTNER,
x 3,300, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-588-6.
- Fig. 9 Tubodiscus verenae THIERSTEIN, Proximal side,
x 2,000, Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-600-19.
- Fig. 10 Manivitella pemmatoidea (DEFLANDRE), Proximal side,
x 3,800, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-590-8.
- Fig. 11 Manivitella pemmatoidea (DEFLANDRE), Distal side,
x 4,400, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-590-9.
- Fig. 12 Manivitella pemmatoidea (DEFLANDRE), Proximal side,
x 3,800, Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-596-7.
- Fig. 13 Parhabdolithus embergeri (NOEL), Distal side,
x 2,800, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-588-20.
- Fig. 14 Parhabdolithus embergeri (NOEL), Side view,
x 2,100, Berriasian D.S.D.P. Site 99A, Neg. no. UCL-588-25.
- Fig. 15 Nannoconus truitti BRONNIMANN,
x 3,000, Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-590-18.

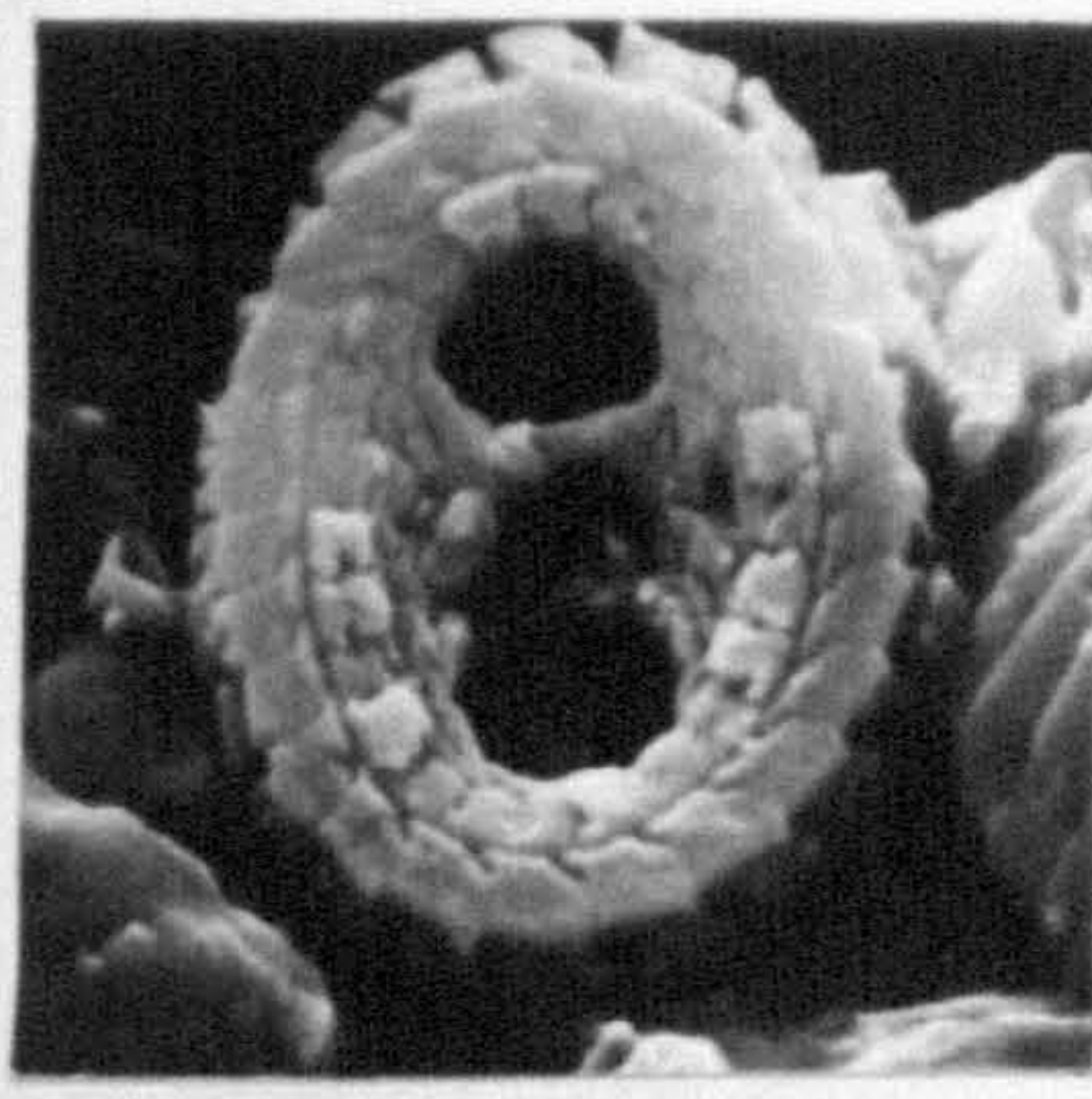
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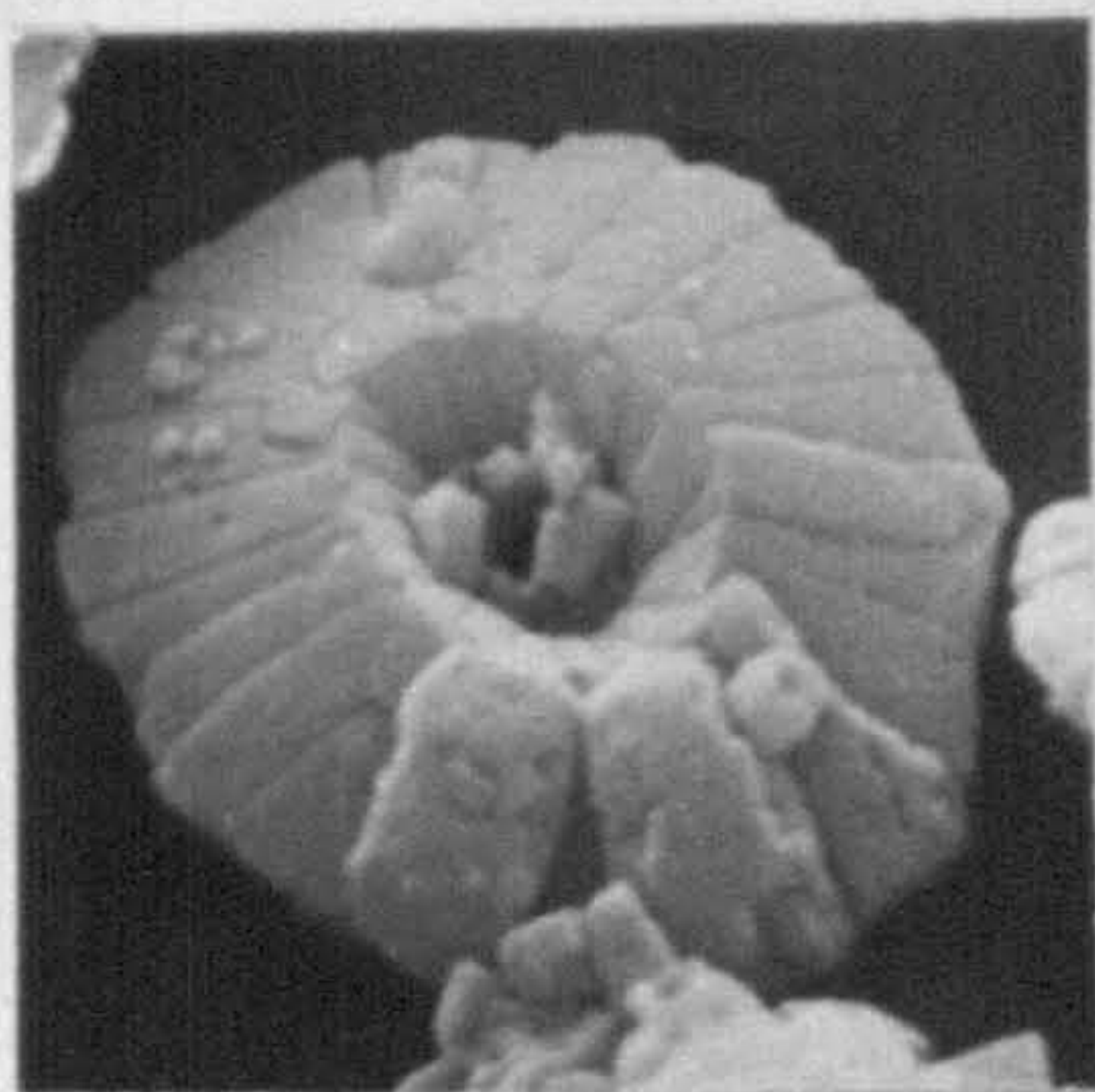
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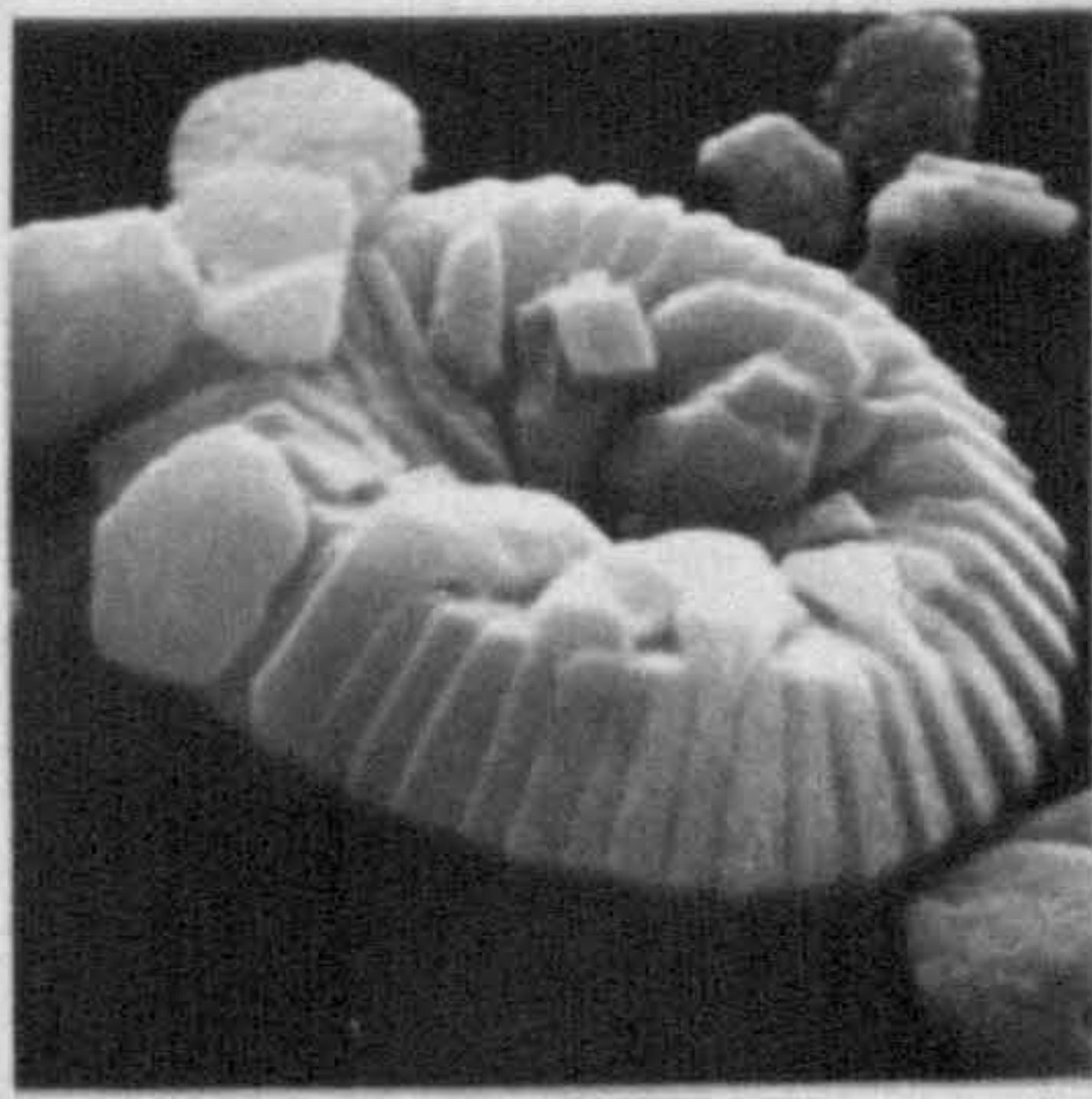
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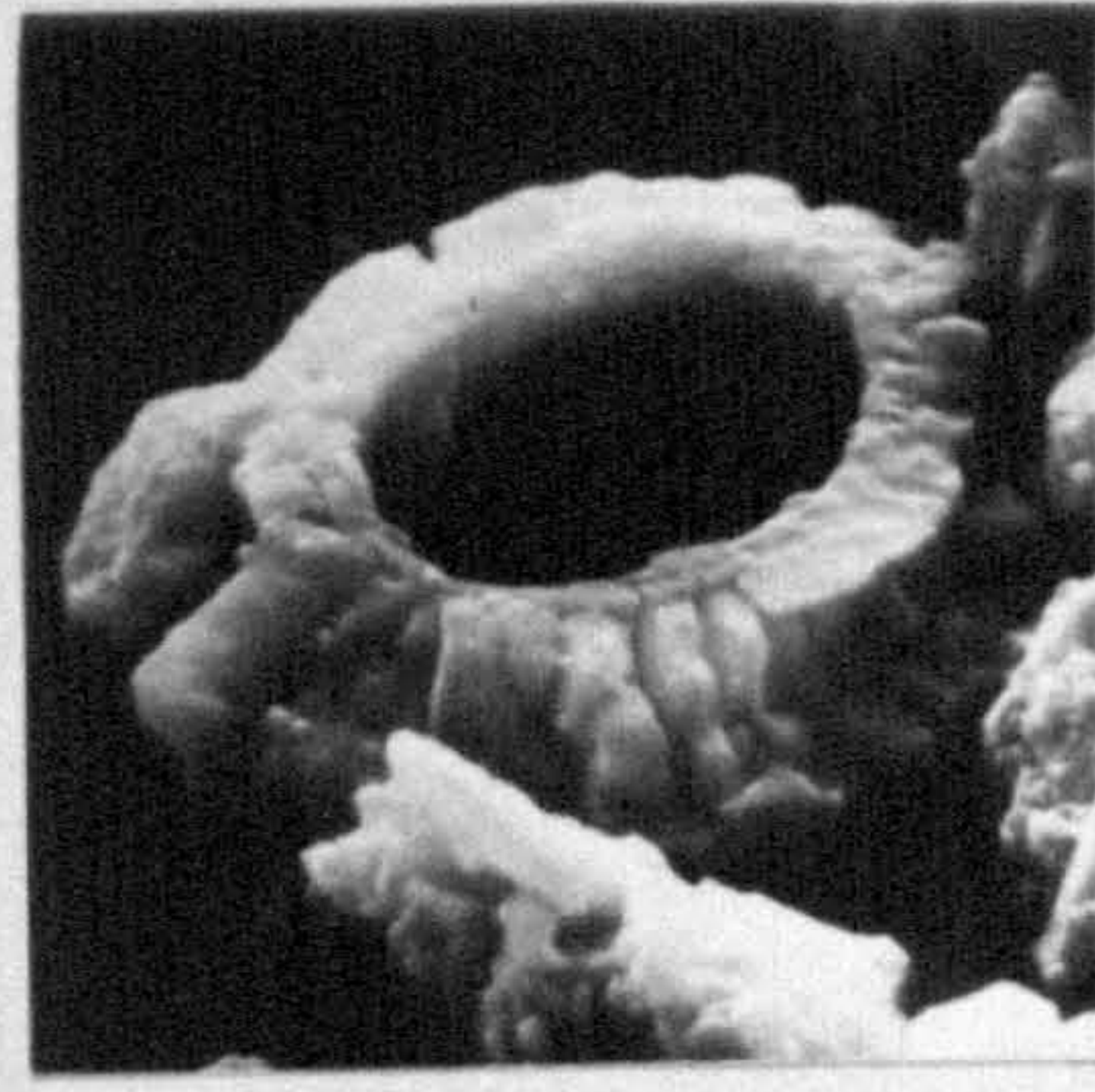
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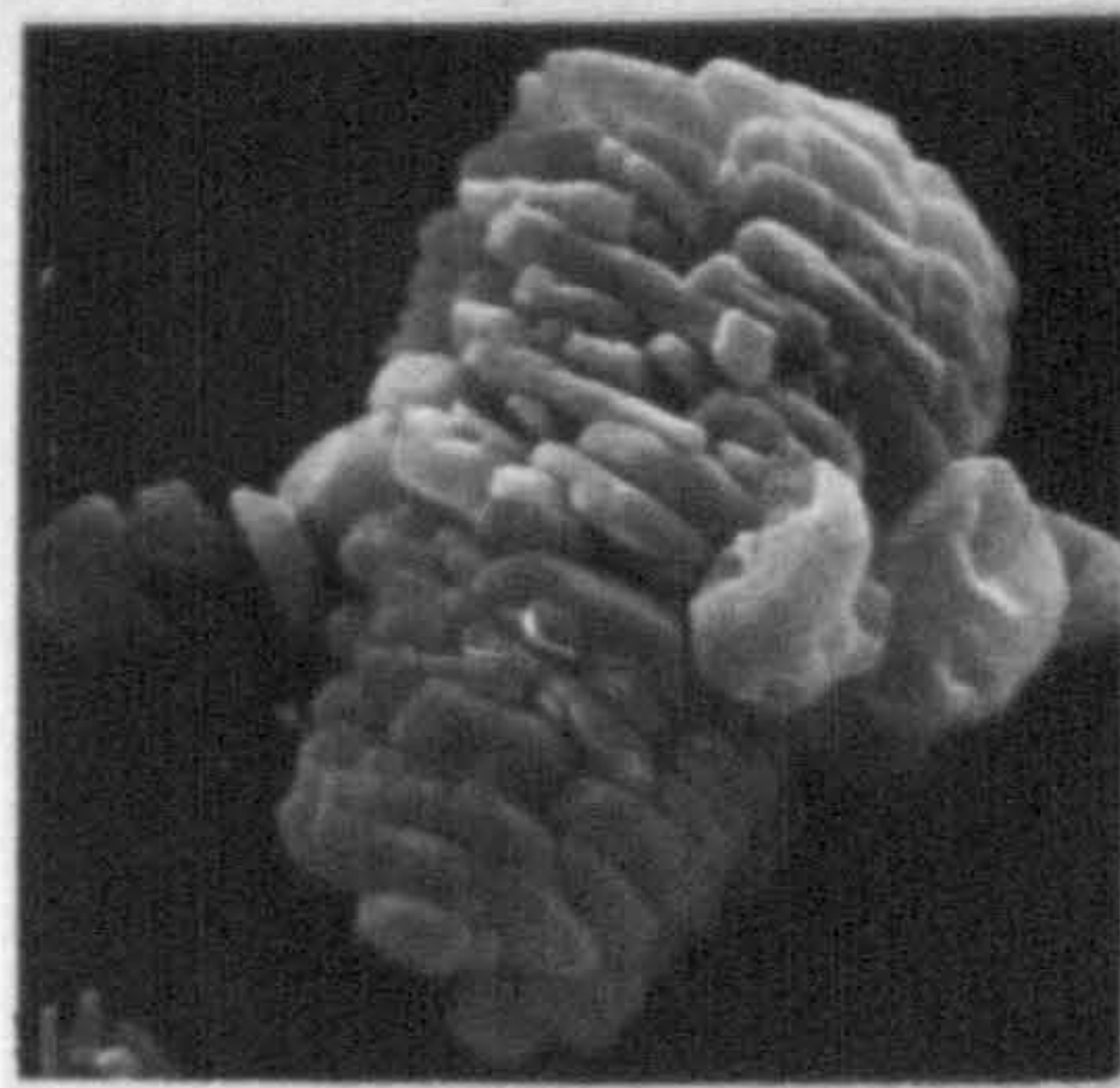
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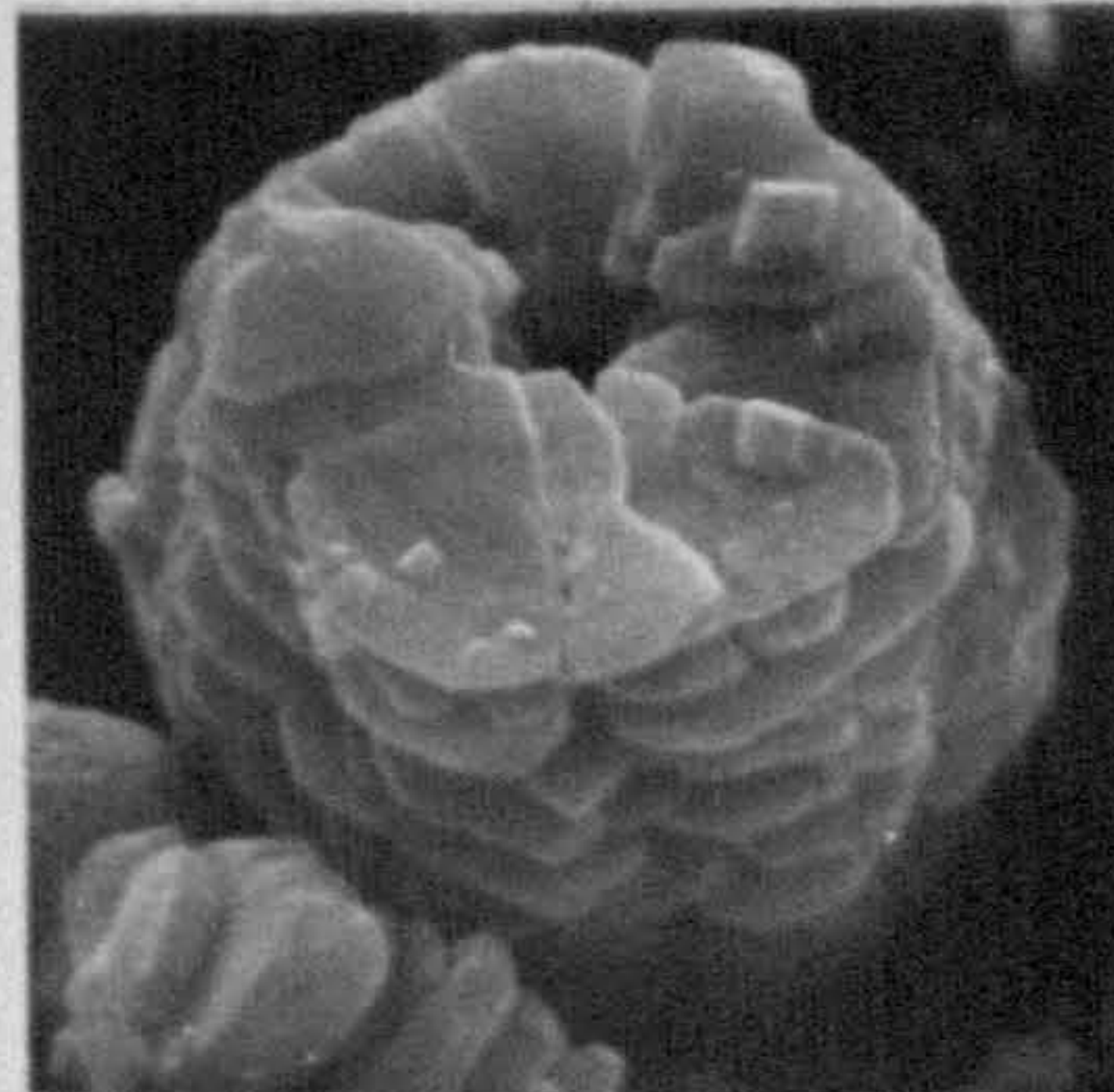
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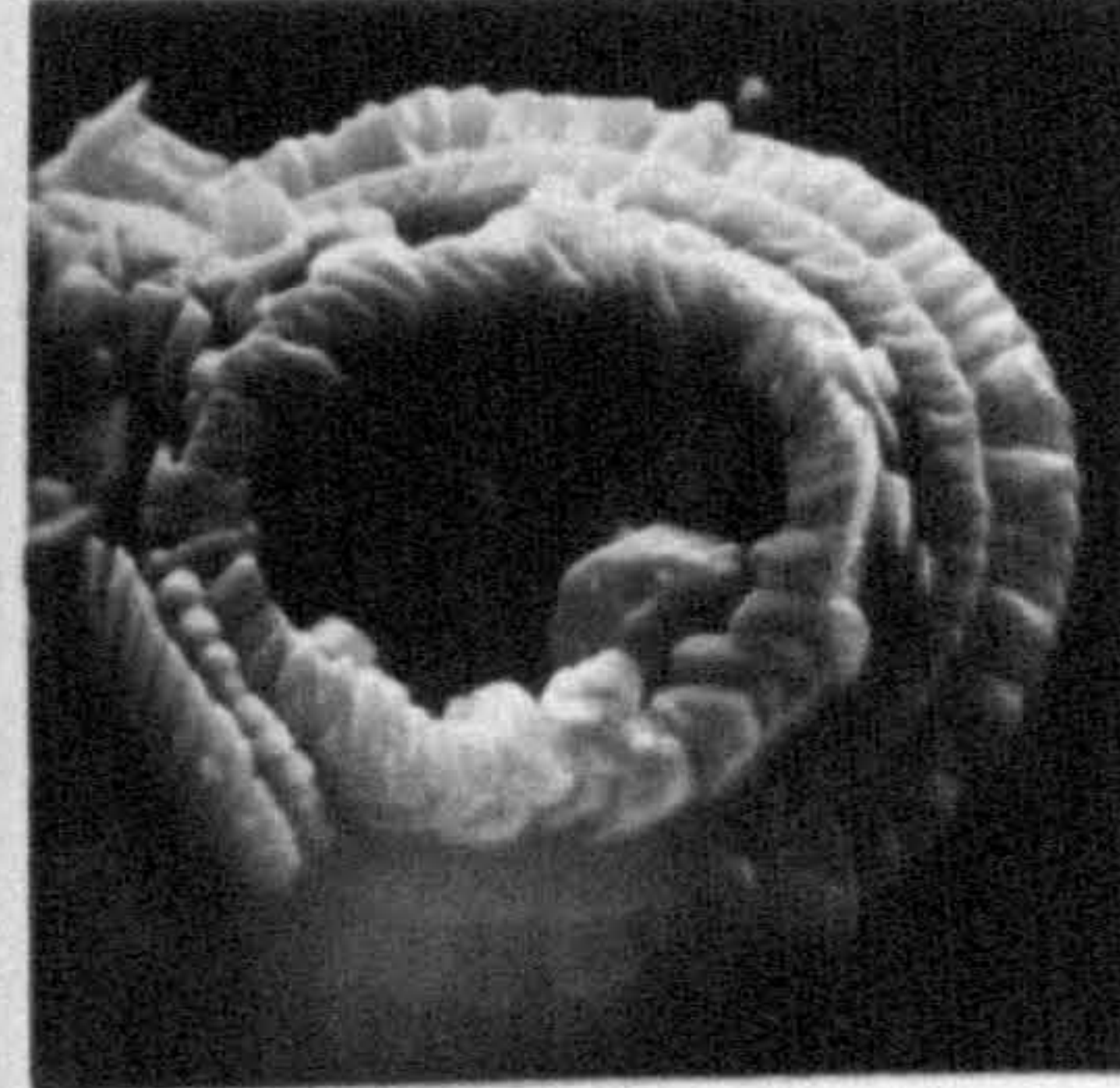
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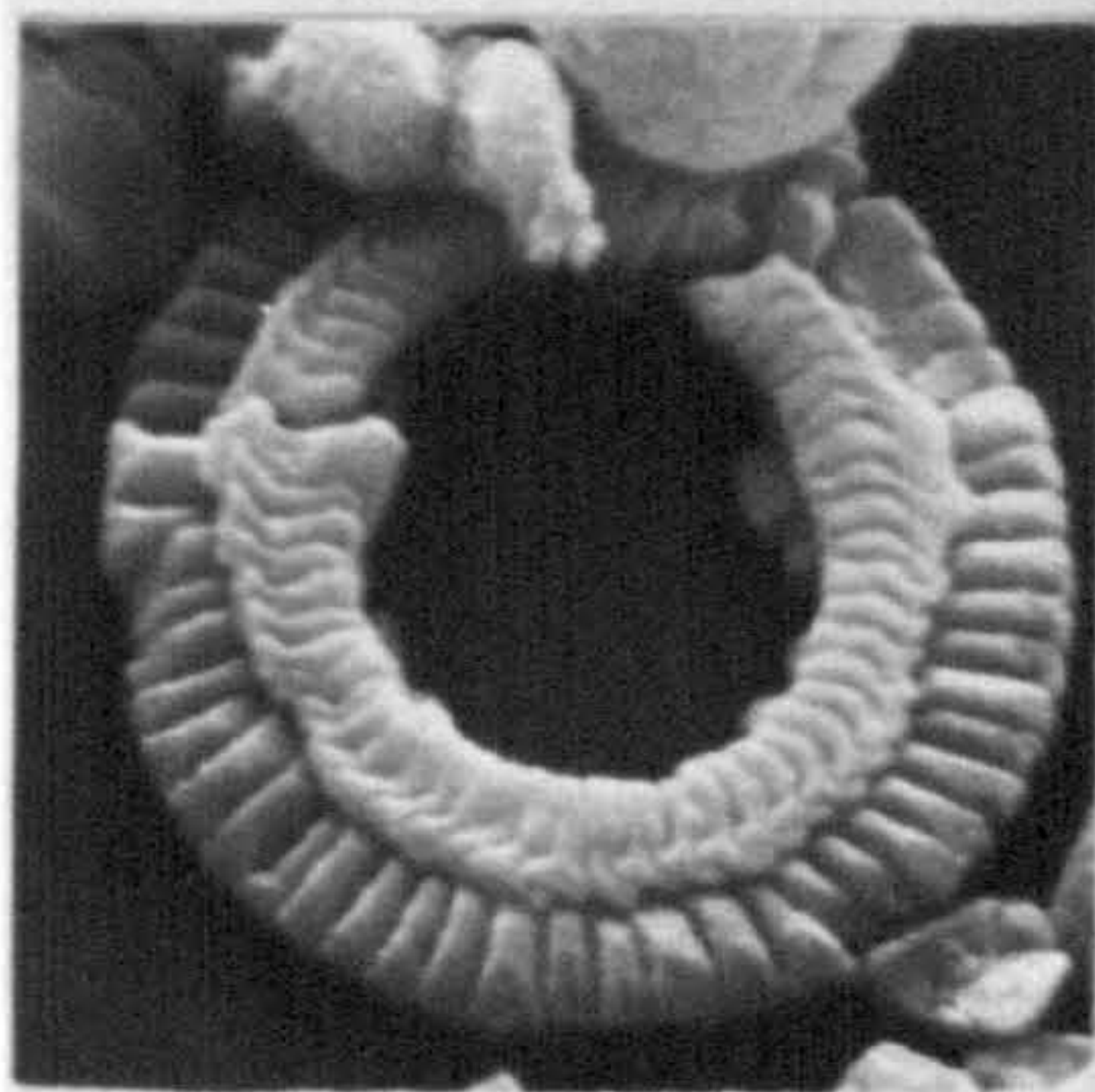
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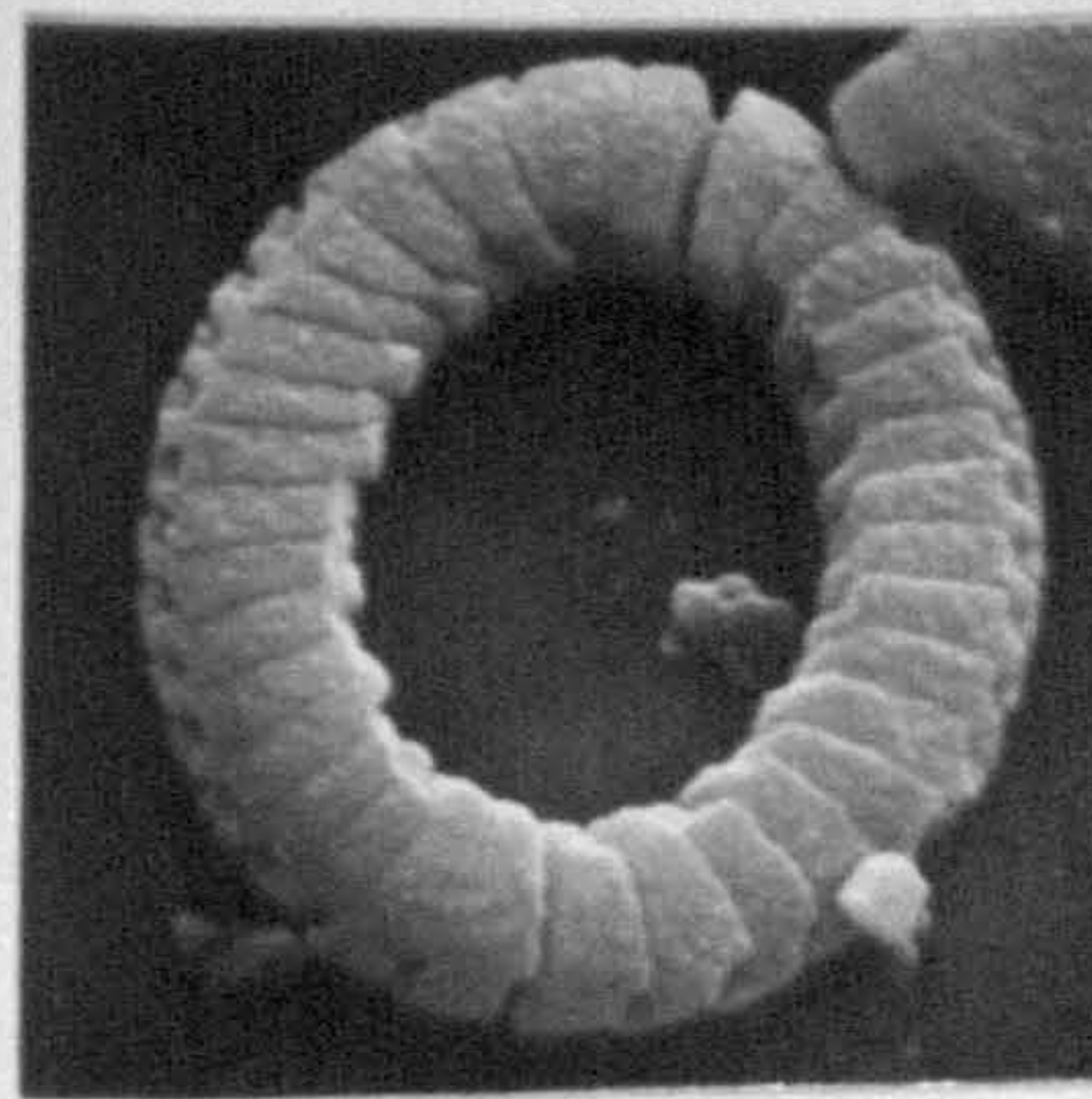
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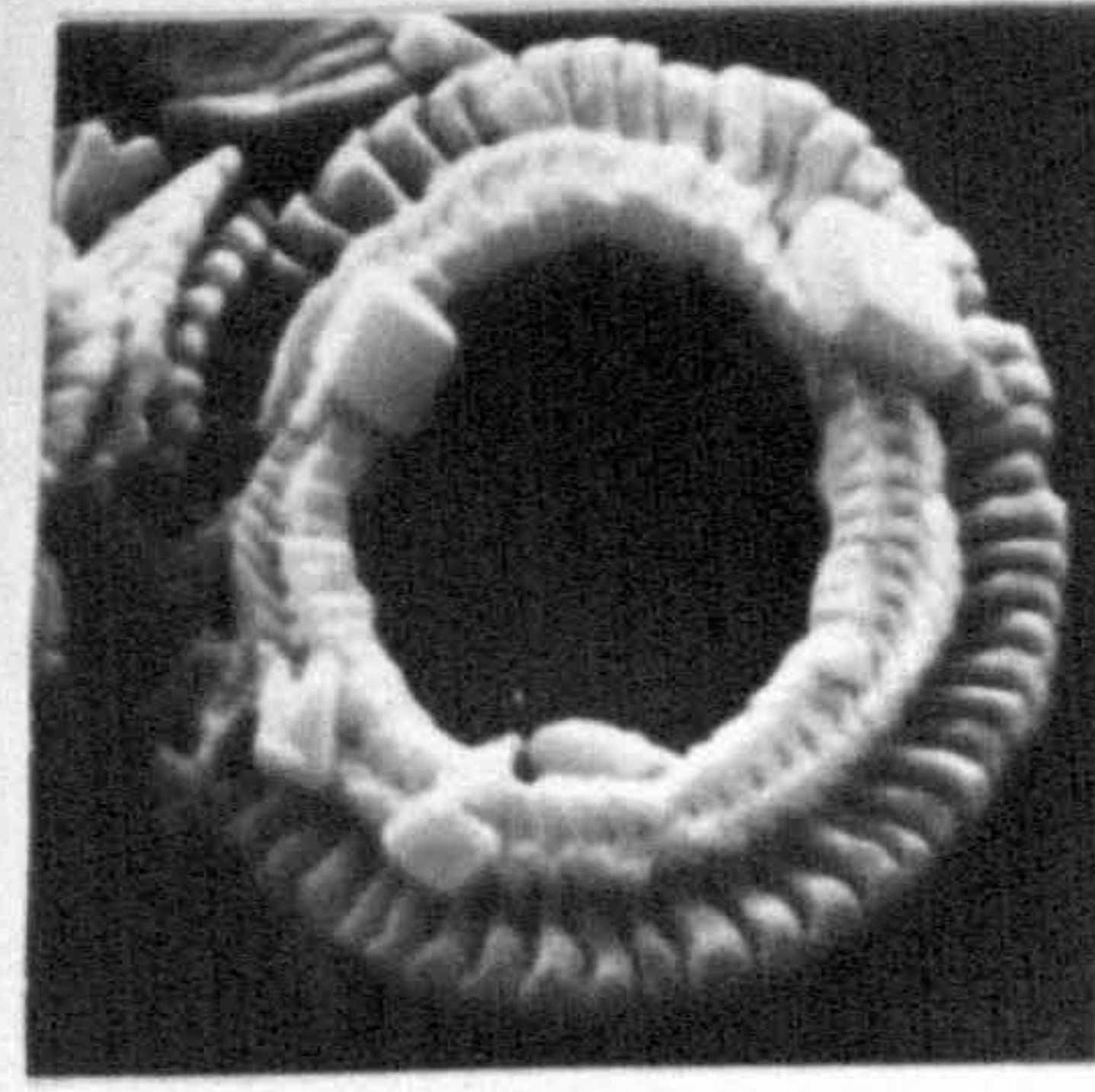
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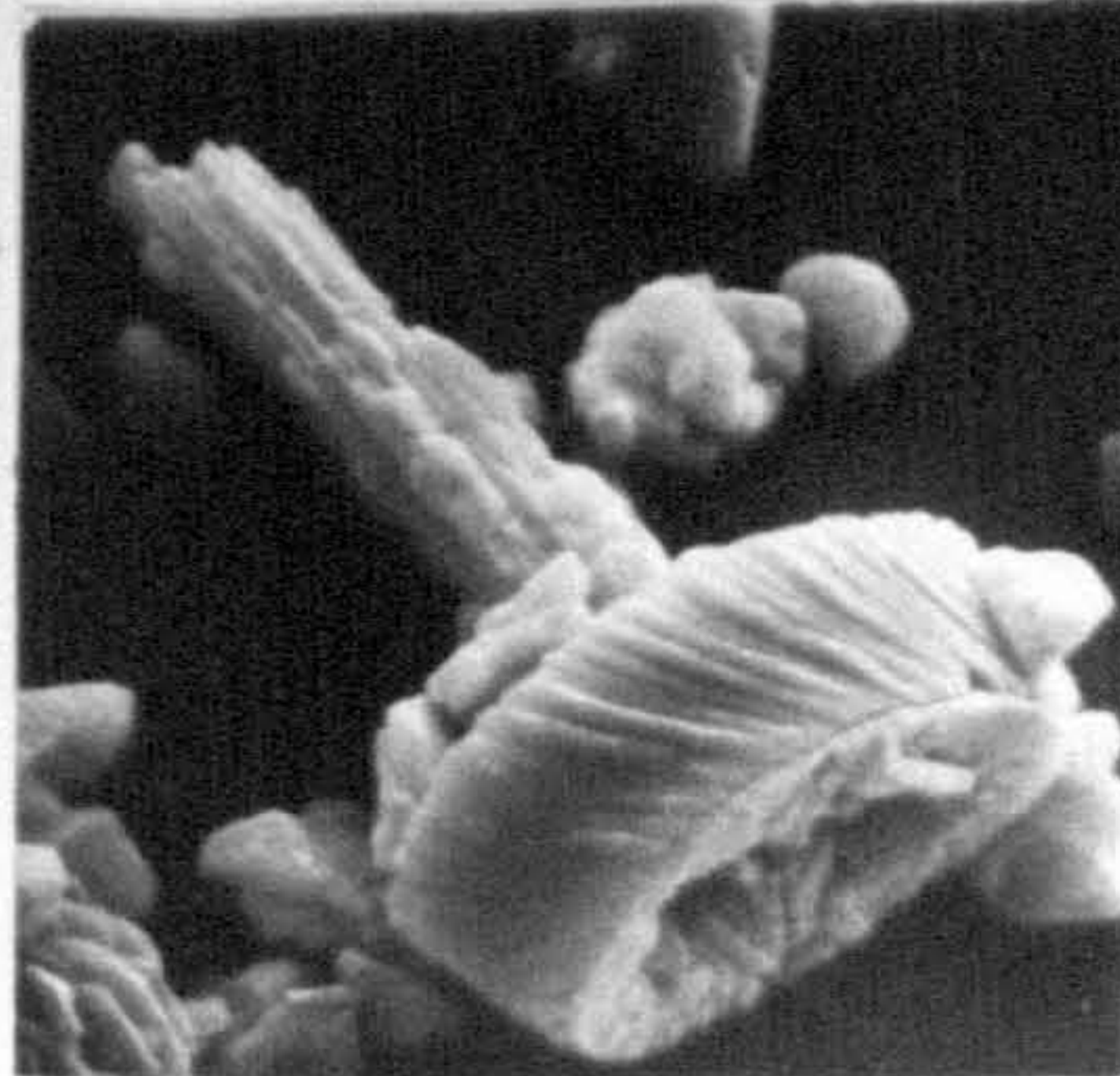
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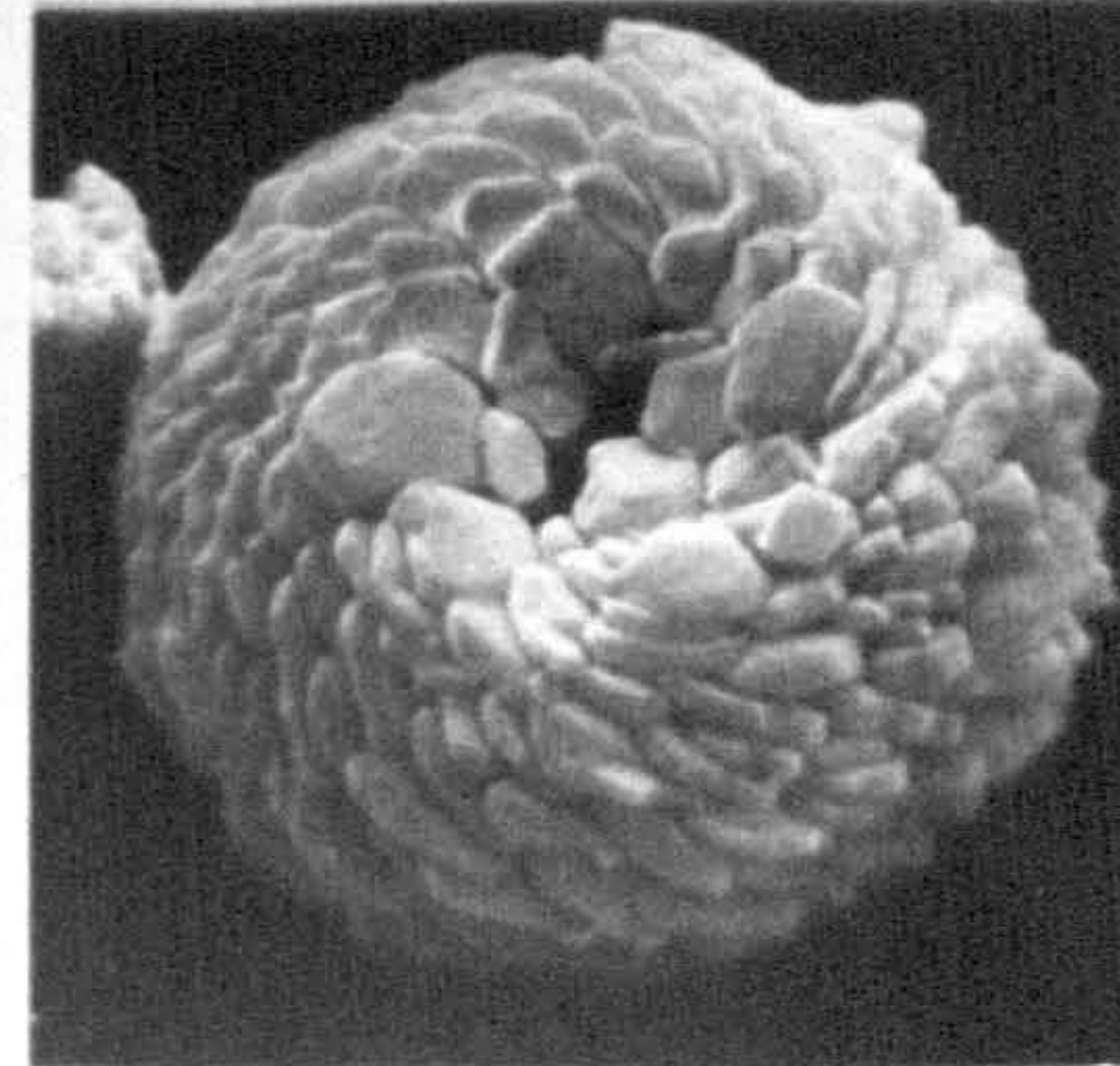
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PLATE 7

- Fig. 1 Tubirhabdus patulus PRINS, x 2,500
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-75-6.
- Fig. 2 Crepidolithus crucifer PRINS, x 2,400
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-75-2.
- Fig. 3 Crepidolithus cavus PRINS, x 1,900
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-78-29.
- Fig. 4 Crepidolithus crassus (DEFLANDRE), x 2,200
Upper Sinemurian, Brenha Rd., Neg. no. UCL-79-16.
- Fig. 5 Schizosphaerella punctulata DEFLANDRE & DANGEARD, x 1,300
Toarcian, Brenha Rd. Neg. no. UCL-81-4.
- Fig. 6 Markalius inversus (DEFLANDRE), x 1,800
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-702-3.
- Fig. 7 Podorhabdus macrogranulatus PRINS, x 2,500
Toarcian, Brenha Rd., Neg. no. UCL-77-5.
- Fig. 8 Parhabdolithus sp., x 1,900
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-80-4.
- Fig. 9 Staurolithites crux (DEFLANDRE), x 2,900
Oxfordian, D.S.D.P. Site 105, Neg. no. UCL-686-3.
- Fig. 10 Podorhabdus cylindratus NOEL, x 3,200
Bathonian, Brenha Rd., Neg. no. UCL-344-8.
- Fig. 11 Diazomatolithus lehmani NOEL, x 2,700
Toarcian, Brenha Rd., Neg. no. UCL-82-36.
- Fig. 12 Diazomatolithus lehmani NOEL, x 3,200
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-702-18.
- Fig. 13 Crucirhabdus primulus PRINS, x 2,500
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-75-19.
- Fig. 14 Parhabdolithus liasicus DEFLANDRE, x 2,100
Lower Pliensbachian, Brenha Rd., Neg. no. UCL-71-22.
- Fig. 15 Parhabdolithus marthae DEFLANDRE, x 2,500
Upper Sinemurian, Brenha Rd., Neg. no. UCL-73-25.
- Fig. 16 Parhabdolithus marthae DEFLANDRE, x 2,900
Upper Sinemurian, Brenha Rd., Neg. no. UCL-75-19.
- Fig. 17 Discorhabdus patulus (DEFLANDRE), x 2,200
Toarcian, Brenha Rd., Neg. no. UCL-82-31.

- Fig. 18 Discorhabdus tubus NOEL, x 1,600
Toarcian, Brenha Rd., Neg. no. UCL-78-11.
- Fig. 19 Carinolithus superbus PRINS, x 1,700
Toarcian, Brenha Rd., Neg. no. UCL-78-13.
- Fig. 20 Discorhabdus jungi NOEL, x 1,900
Bathonian, Cap Mondego, Neg. no. UCL-422-17.
- Fig. 21 Conusphaera mexicana TREJO, x 1,900
Tithonian, D.S.D.P. Site 105, Neg. no. UCL-656-19.
- Fig. 22 Discoaster sp. 1, x 2,000
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-19.
- Fig. 23 Discoaster sp. 2, x 1,400
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-23.
- Fig. 24 Discoaster sp. 3, x 1,400
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-25.

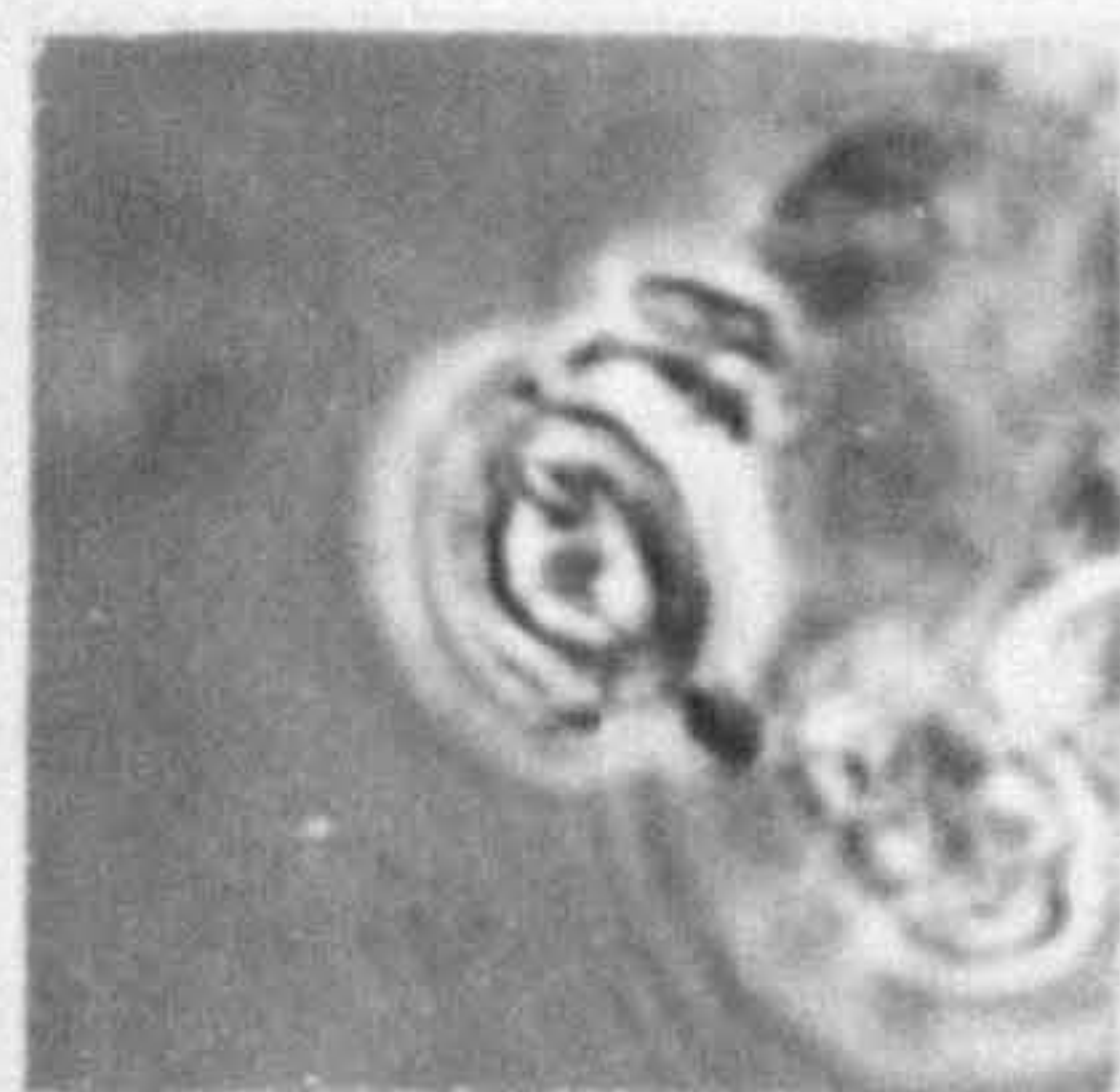
PLATE 7



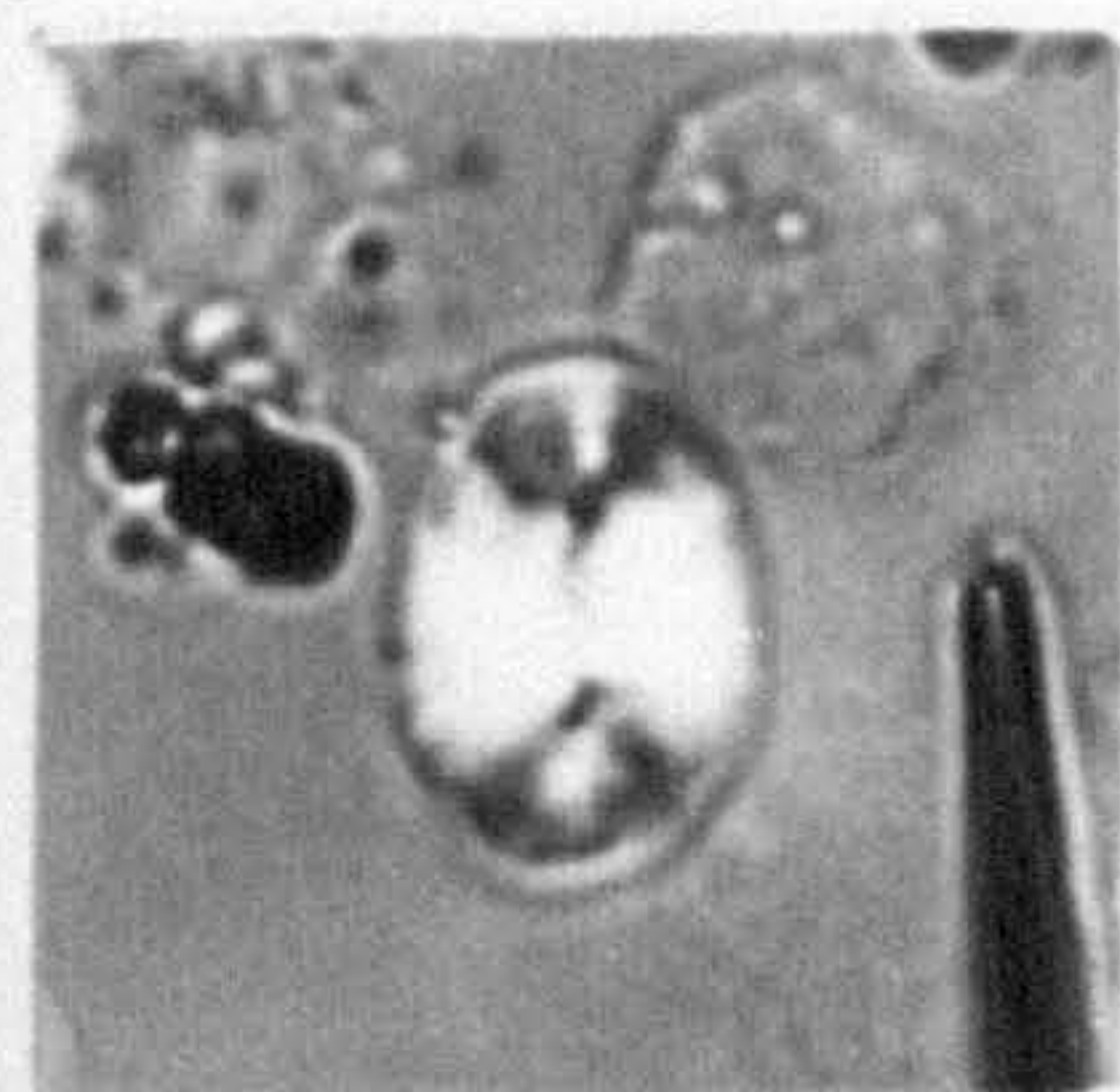
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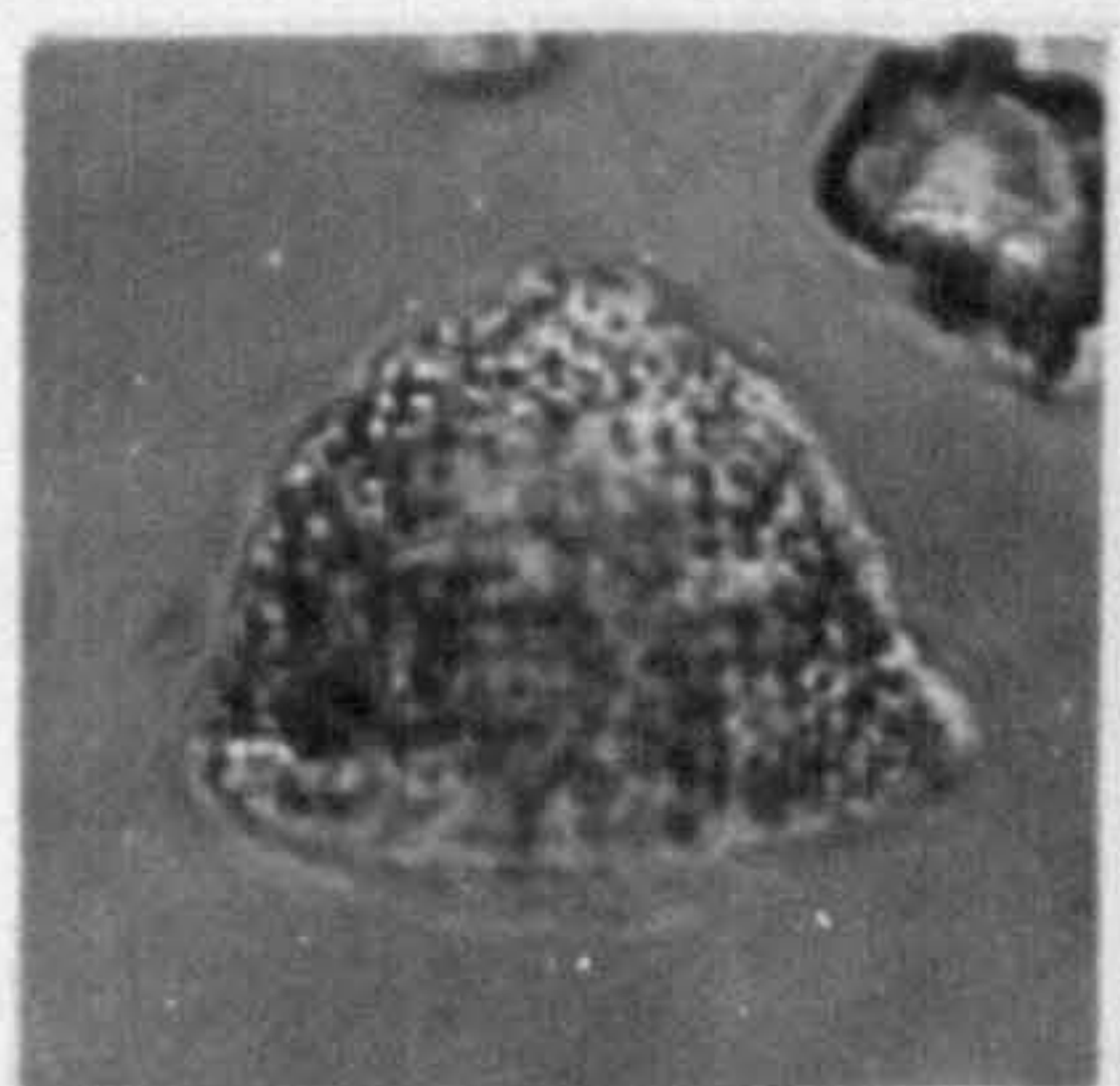
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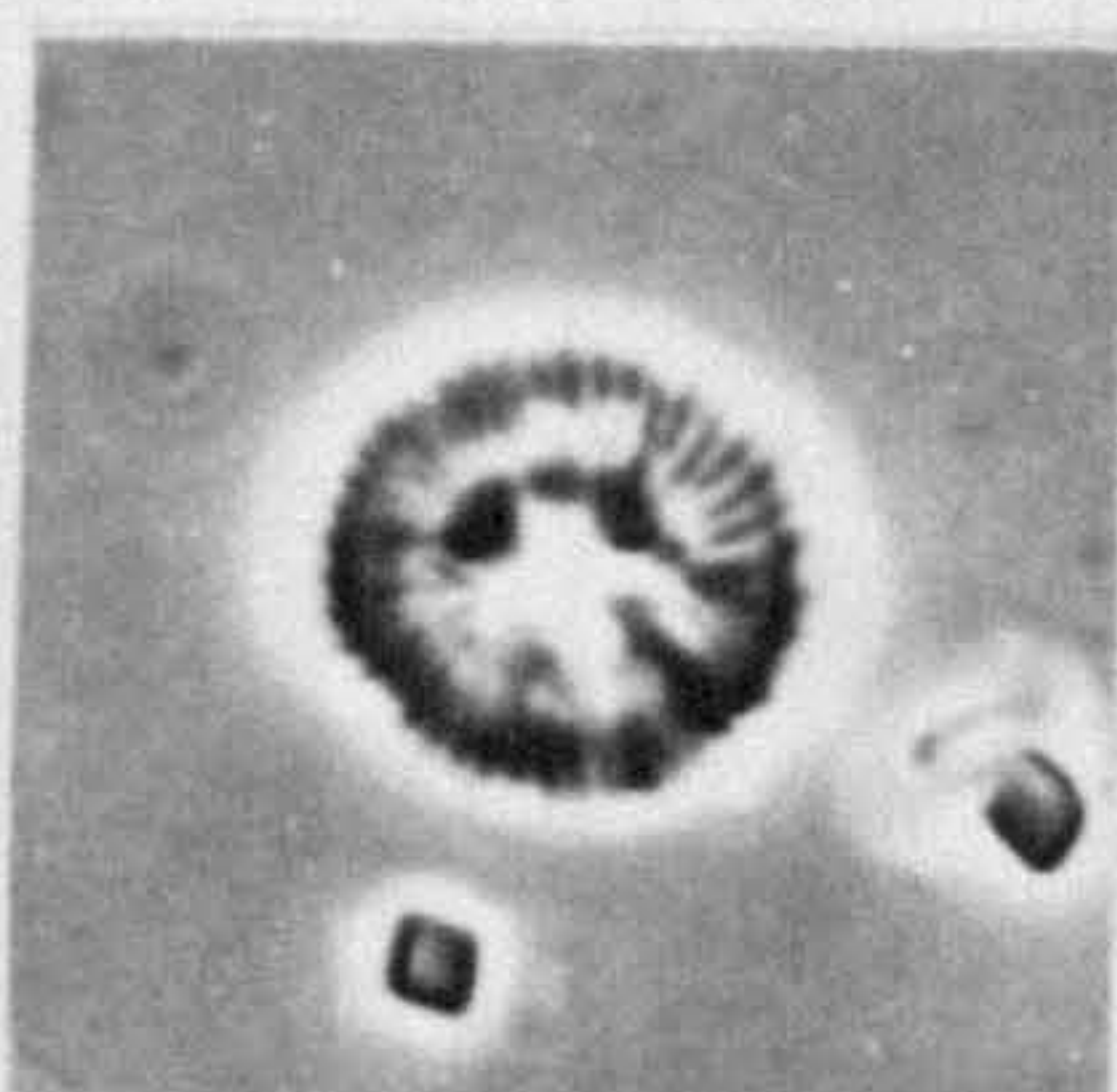
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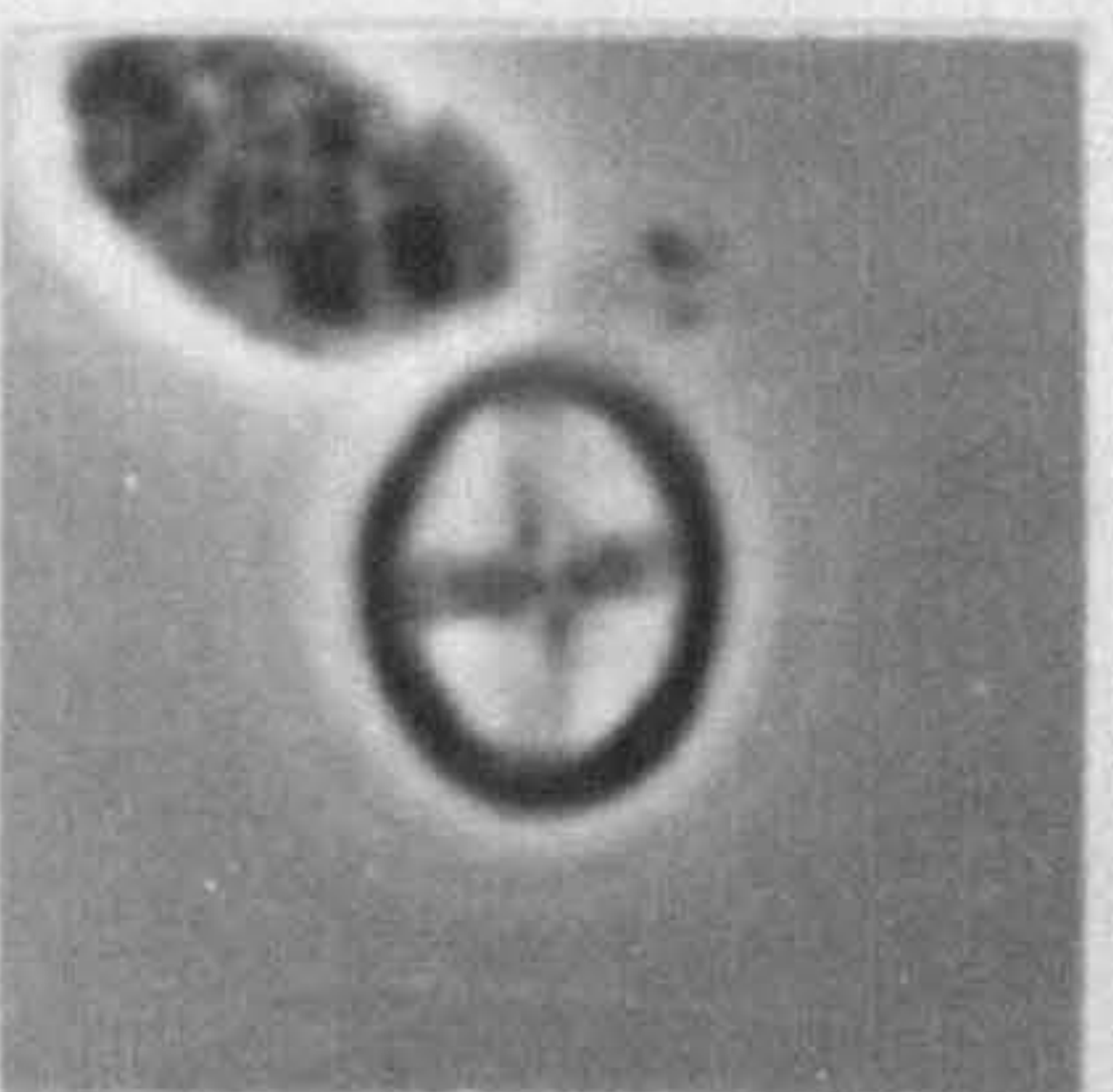
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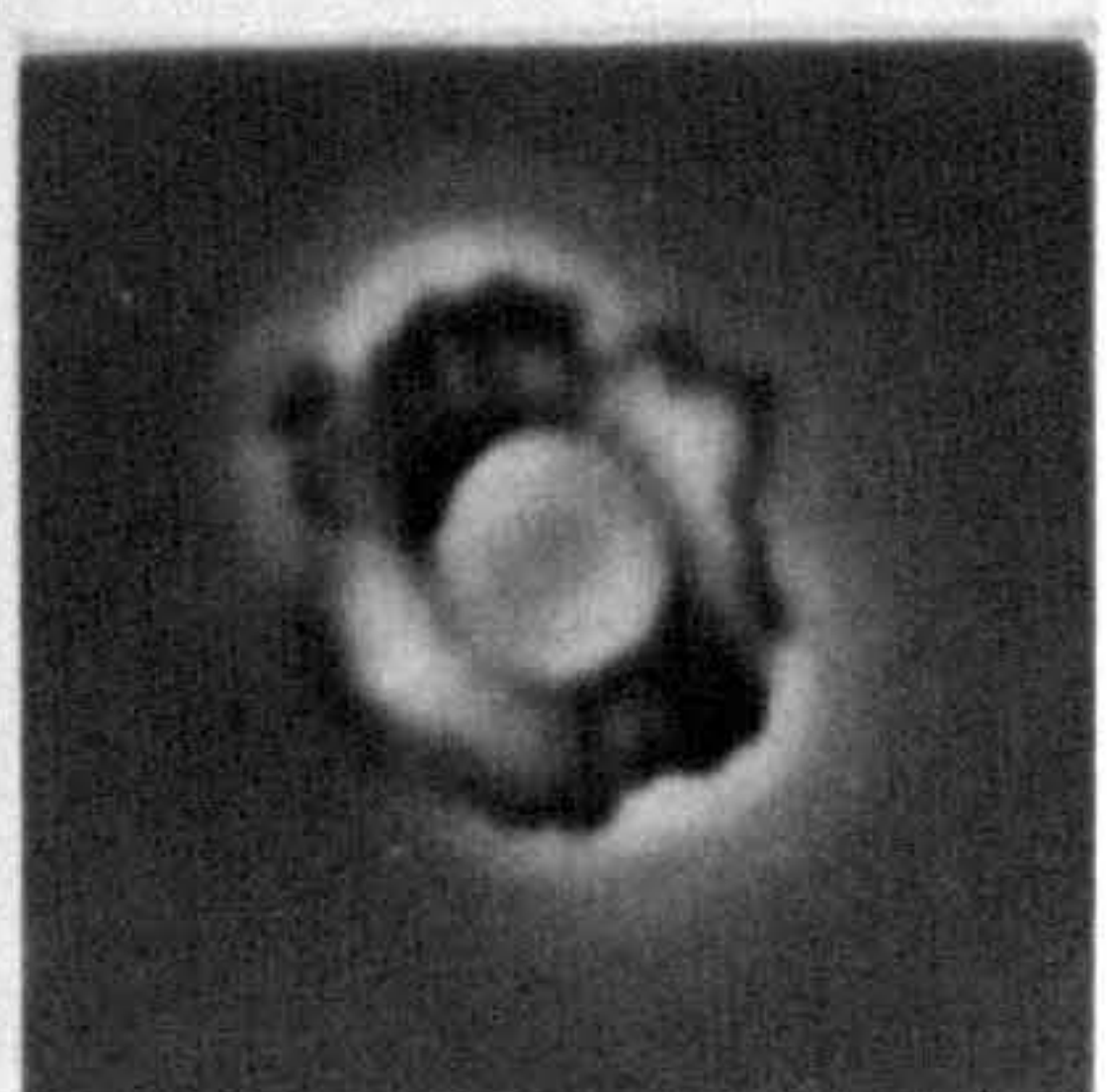
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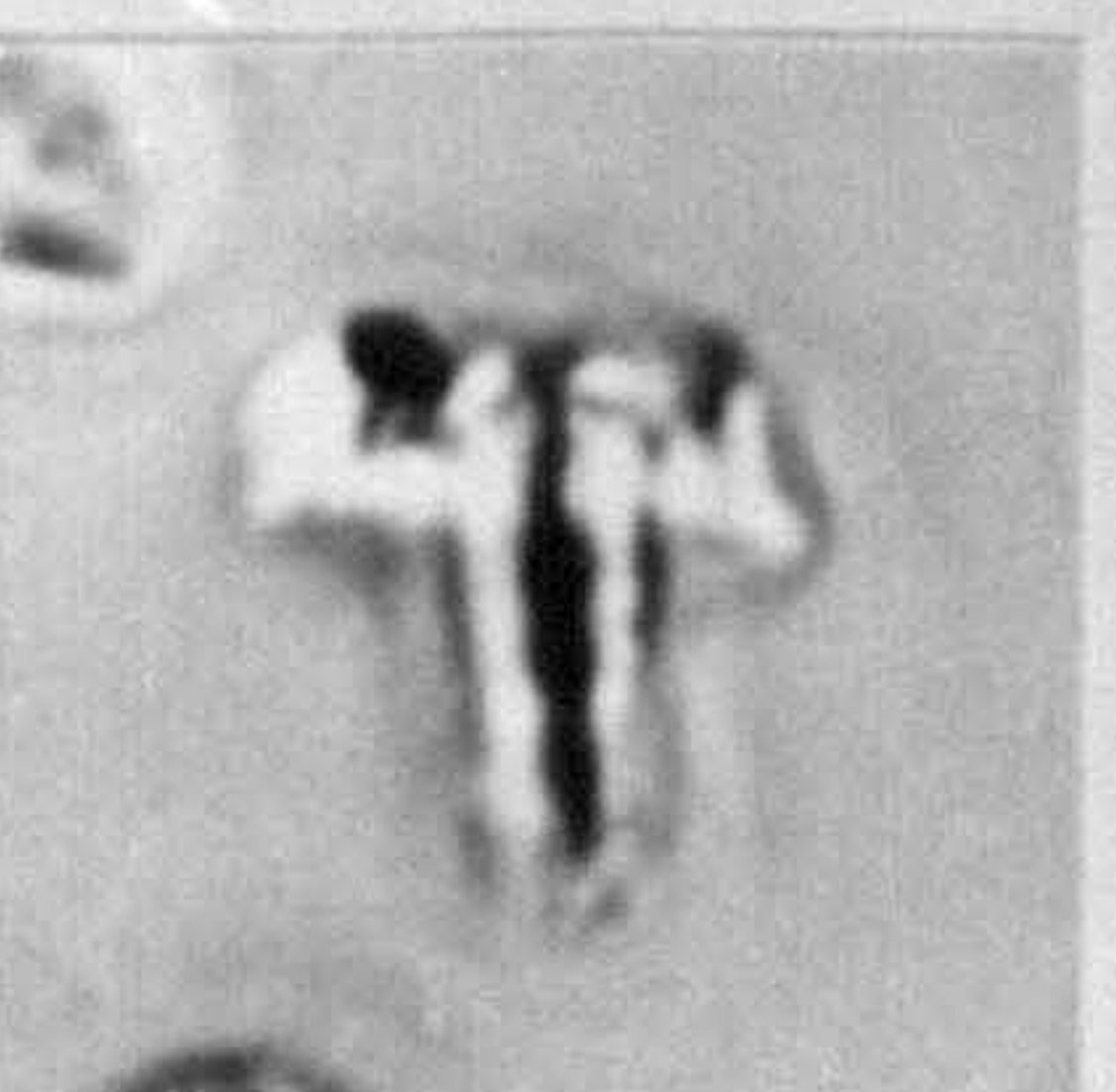
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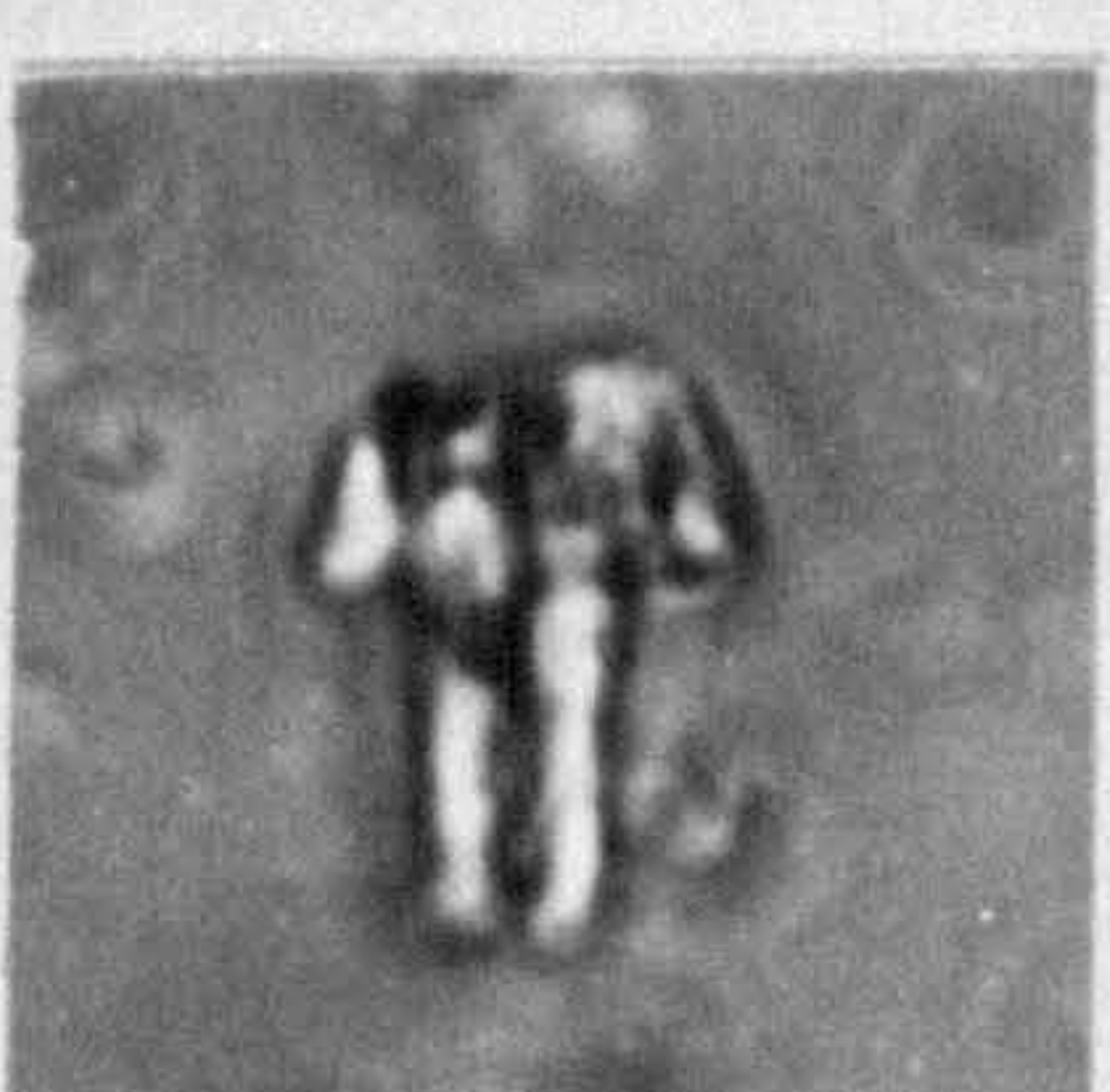
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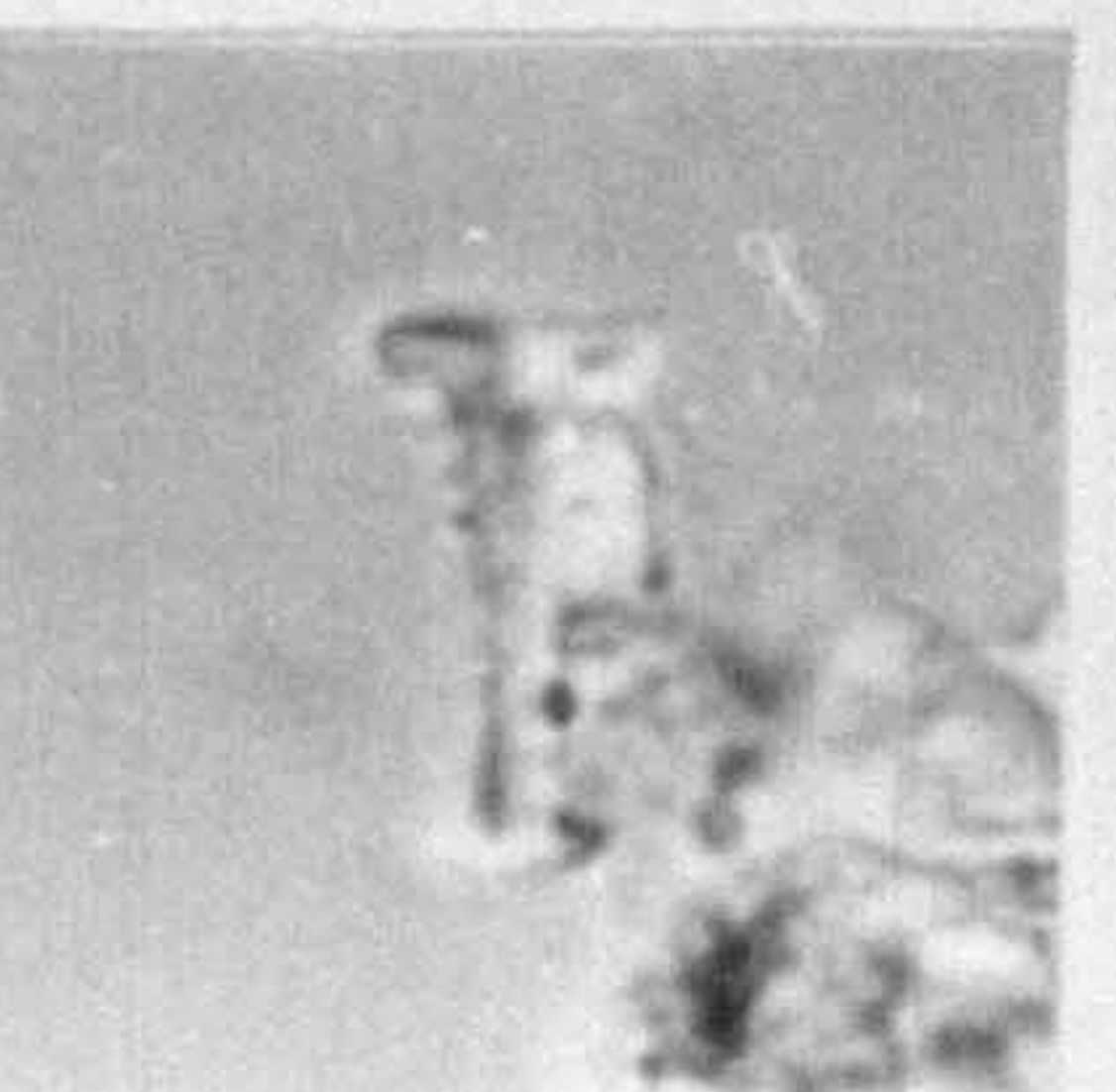
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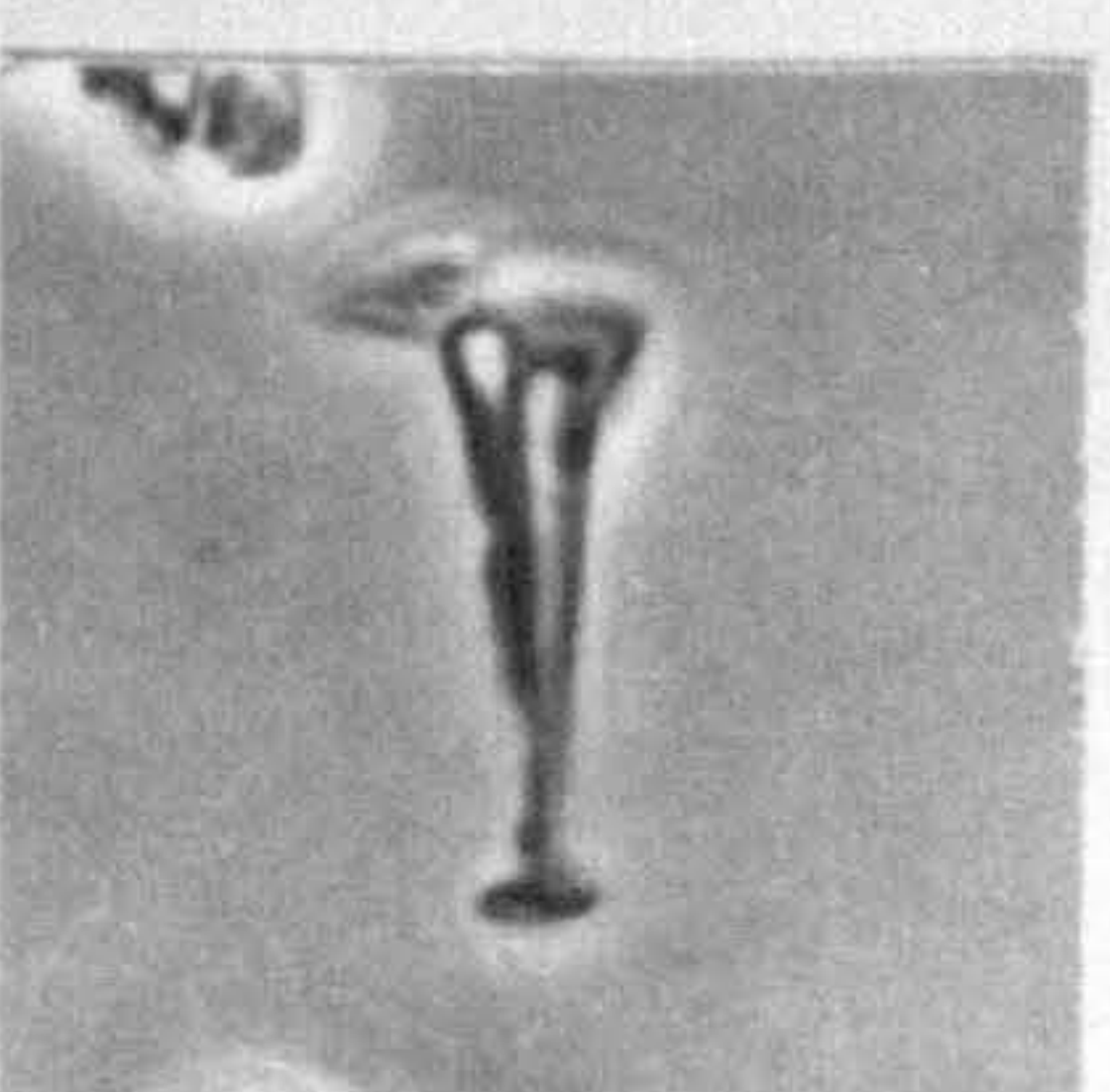
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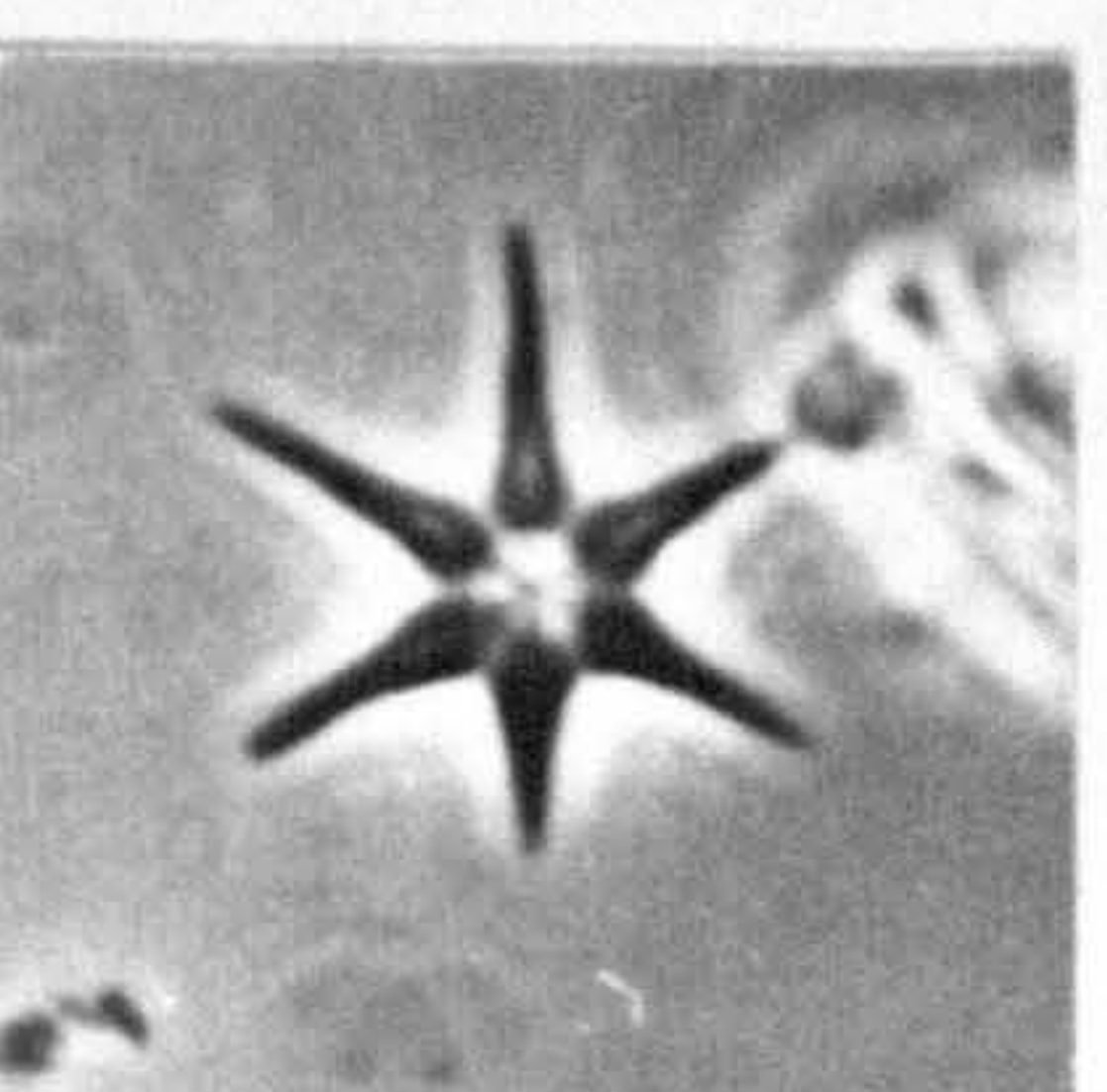
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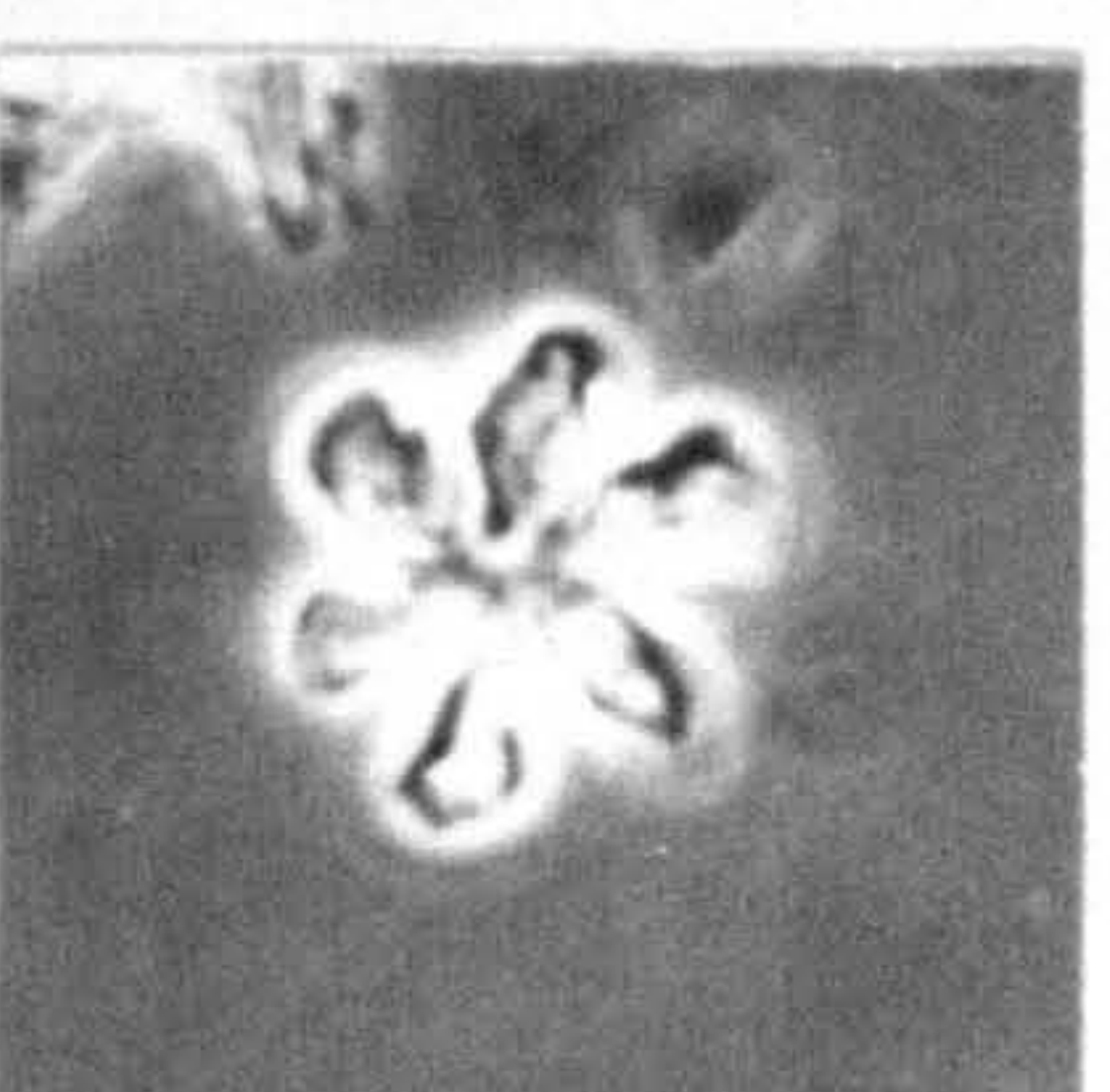
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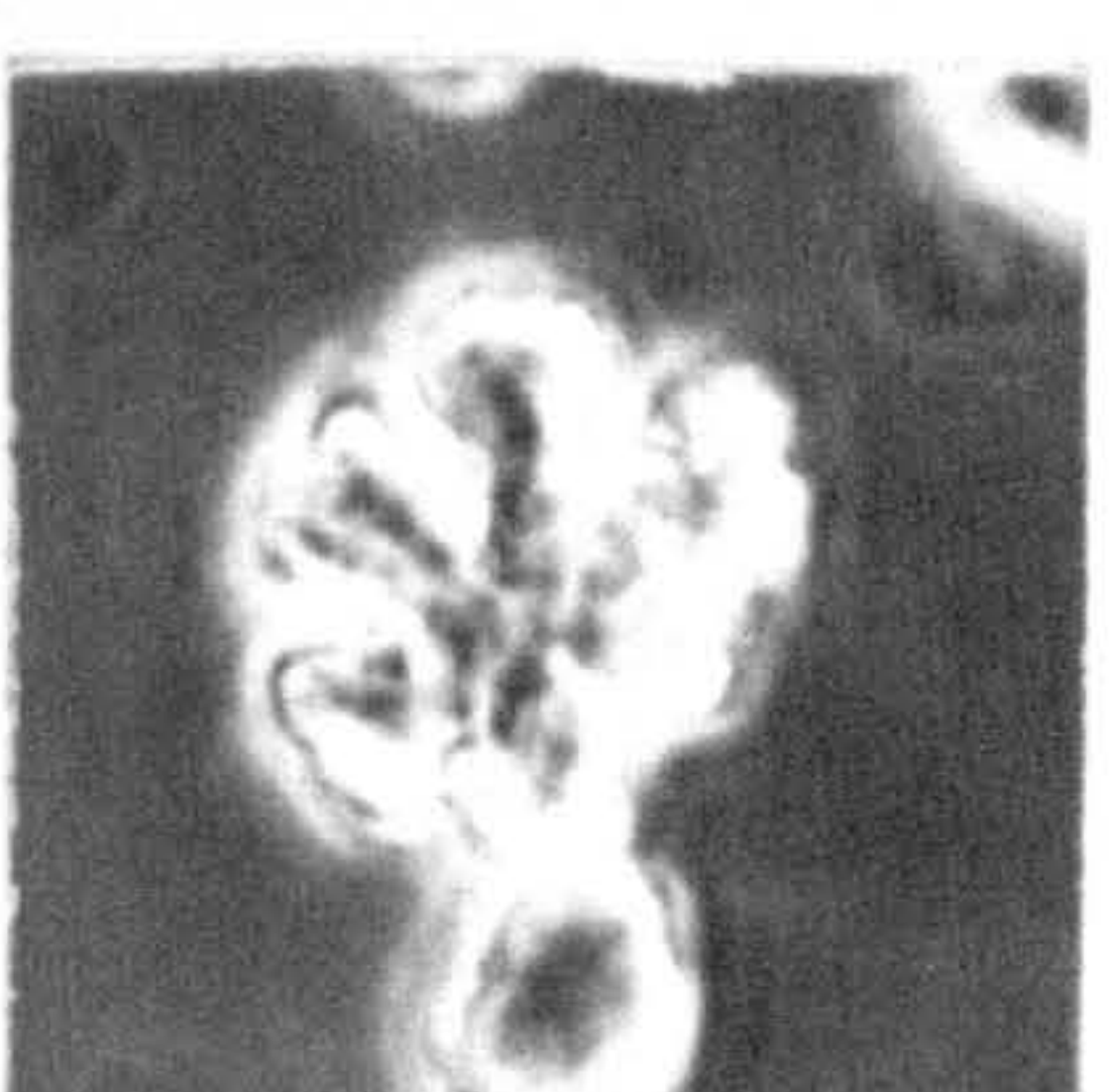
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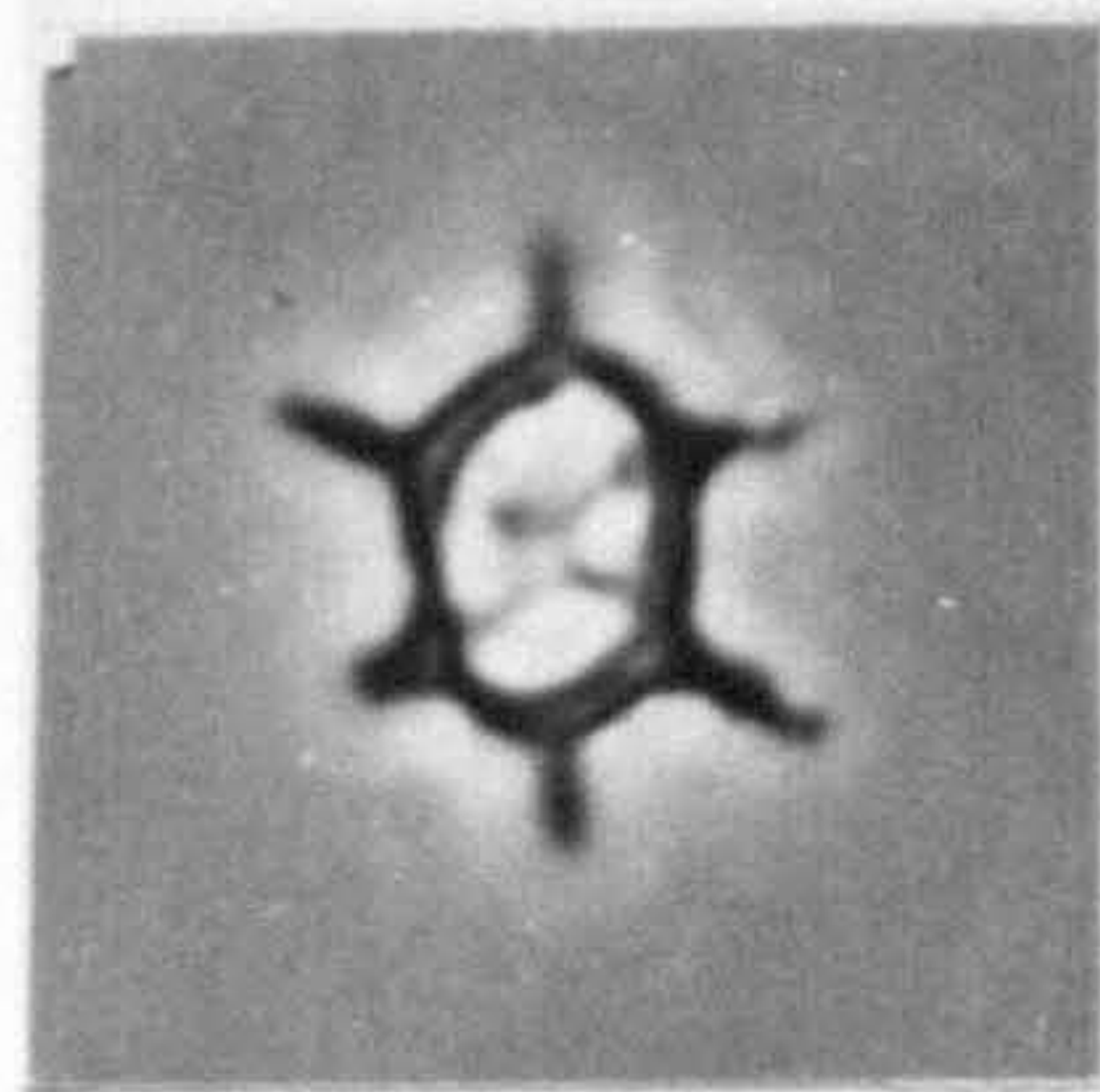
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PLATE 8

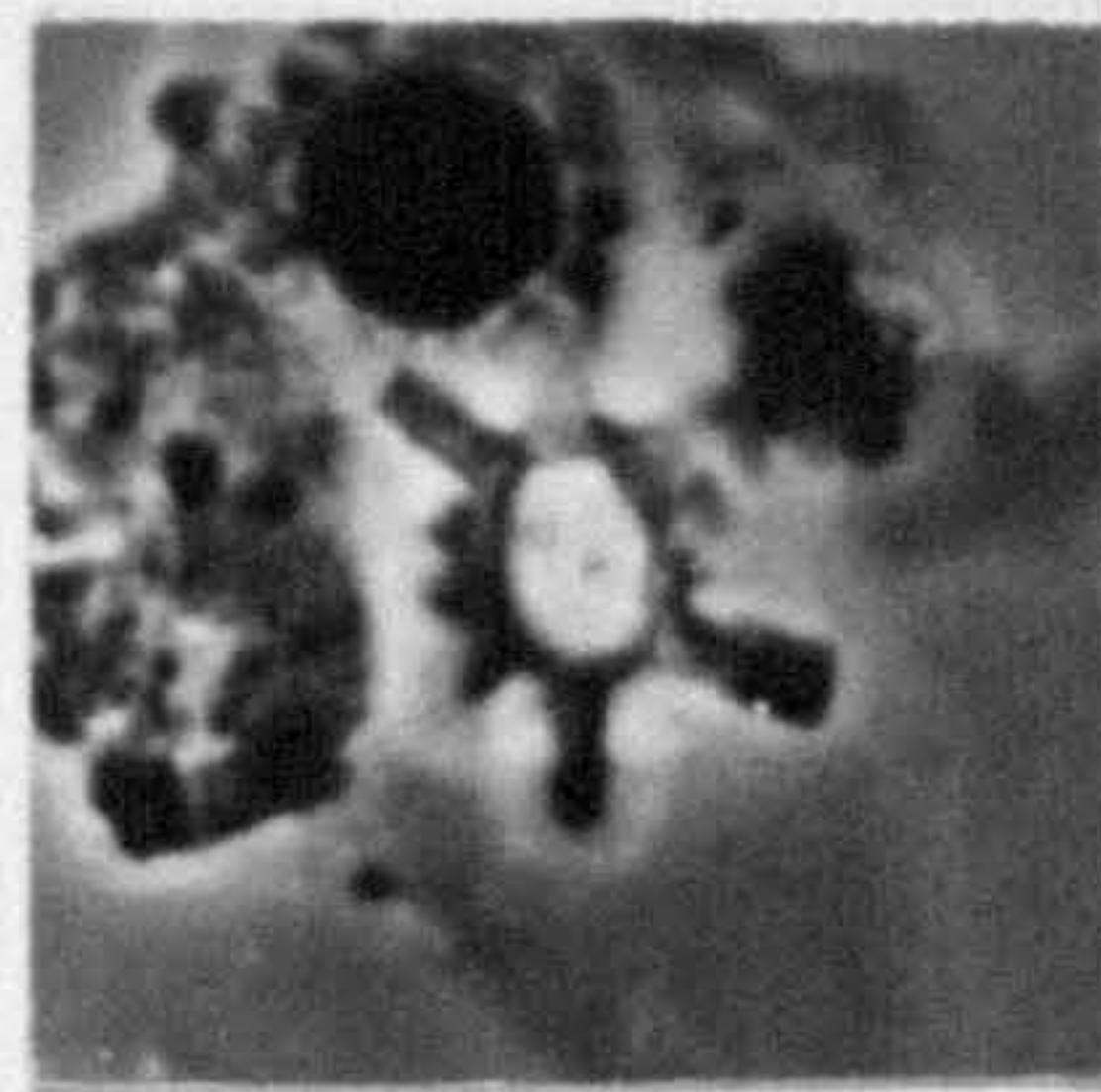
- Fig. 1 Stephanolithion bigoti DEFLANDRE, x 3,000
Upper Callovian, Skye, Neg. no. UCL-432-27.
- Fig. 2 Stephanolithion bigoti DEFLANDRE, x 1,800
Upper Callovian, Skye, Neg. no. UCL-712-15.
- Fig. 3 Stephanolithion bigoti DEFLANDRE, x 1,500
Upper Callovian, Skye, Neg. no. UCL-712-1.
- Fig. 4 Stephanolithion bigoti DEFLANDRE, x 1,900
Upper Callovian, Skye, Neg. no. UCL-712-17.
- Fig. 5 Stephanolithion speciosum DEFLANDRE, x 3,200
Bathonian, Brenha Rd., Neg. no. UCL-344-17.
- Fig. 6 Stephanolithion speciosum var. octum ROOD & BARNARD, x 2,900
Bathonian, Brenha Rd., Neg. no. UCL-344-12.
- Fig. 7 Stephanolithion hexum ROOD & BARNARD, x 2,900
Bathonian, Brenha Rd., Neg. no. UCL-344-11.
- Fig. 8 Ellipsagelosphaera crucicentralis MEDD, x 3,800
Bathonian, Brenha Rd., Neg. no. UCL-364-29.
- Fig. 9 Discorhabdus ignotus (GORKA), x 2,600
Bathonian, Brenha Rd., Neg. no. UCL-364-20.
- Fig. 10 Annulithus arkelli ROOD, HAY & BARNARD, x 2,200
Hettangian, Watchet, Neg. no. UCL-706-25.
- Fig. 11 Annulithus arkelli ROOD, HAY & BARNARD, x 3,400
Hettangian, Watchet, Neg. no. UCL-706-24.
- Fig. 12 Diazomatolithus sp., x 1,400
Bathonian, Cap Mondego, Neg. no. UCL-422-24.
- Fig. 13 Tetralithus gothicus DEFLANDRE, x 2,400
Callovian, Cap Mondego, Neg. no. UCL-450-2.
- Fig. 14 Micrantholithus holschulzi (REINHARDT), x 1,500
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-702-14.
- Fig. 15 Micrantholithus holschulzi (REINHARDT), x 1,800
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-702-15.
- Fig. 16 Parhabdolithus embergeri (NOEL), x 1,100
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-32.
- Fig. 17 Parhabdolithus embergeri (NOEL), x 1,400
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-21.

- Fig. 18 Cruciellipsis cuvillieri (MANIVIT), x1,400
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-692-12.
- Fig. 19 Cruciellipsis cuvillieri (MANIVIT), x 1,400
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-692-9.
- Fig. 20 Tubodiscus verenae THIERSTEIN, x 1,000
Berriasian, D.S.D.P. Site 99A, Neg. no. UCL-692-35.
- Fig. 21 Nannoconus truitti BRONNIMANN, x 1,700
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-6.
- Fig. 22 Nannoconus truitti BRONNIMANN, x 1,700
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-14.
- Fig. 23 Nannoconus steinmanni KAMPTNER, x 1,400
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-8.
- Fig. 24 Nannoconus steinmanni KAMPTNER, x 1,200
Tithonian, D.S.D.P. Site 99A, Neg. no. UCL-692-13.

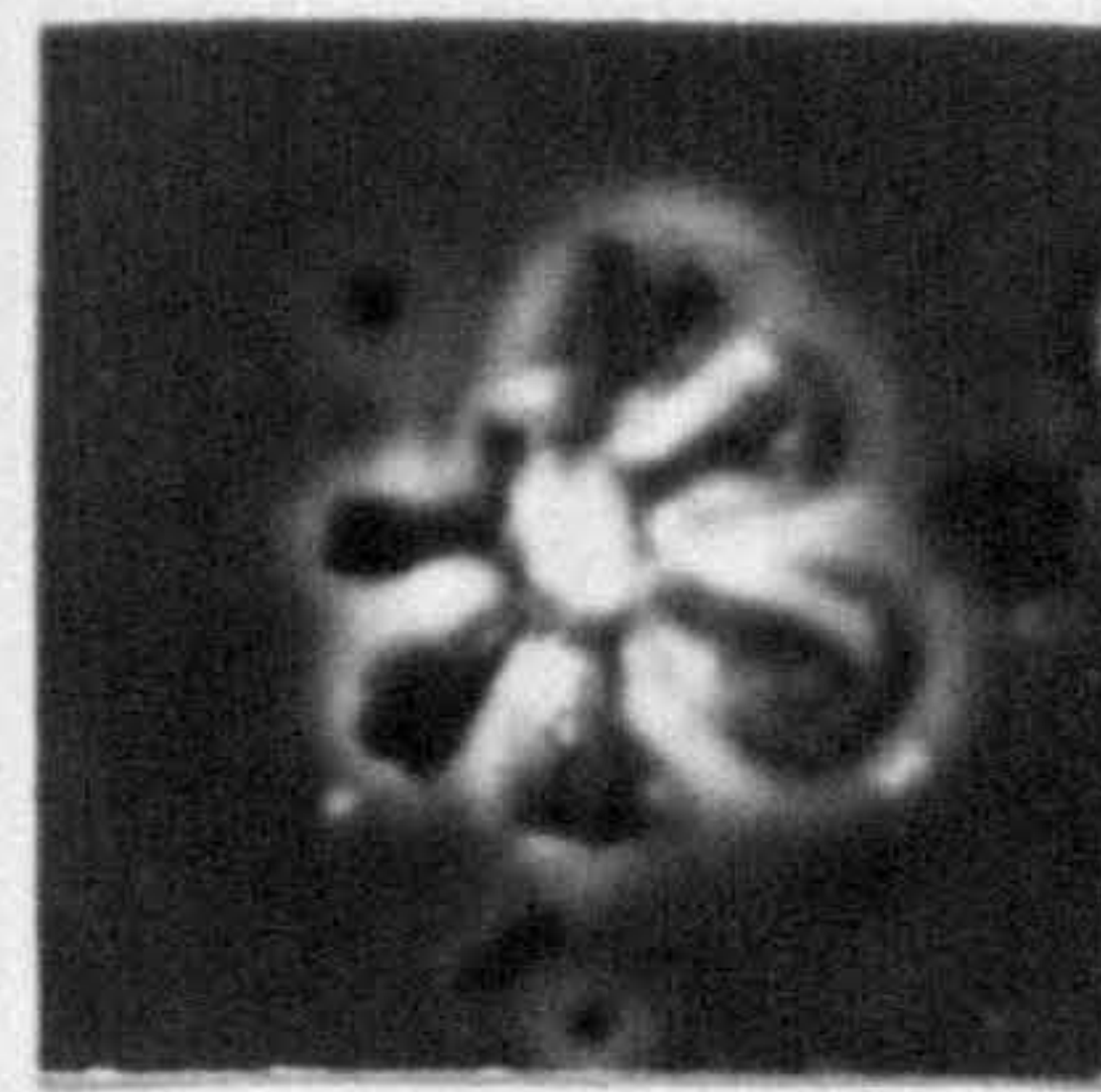
PLATE 8



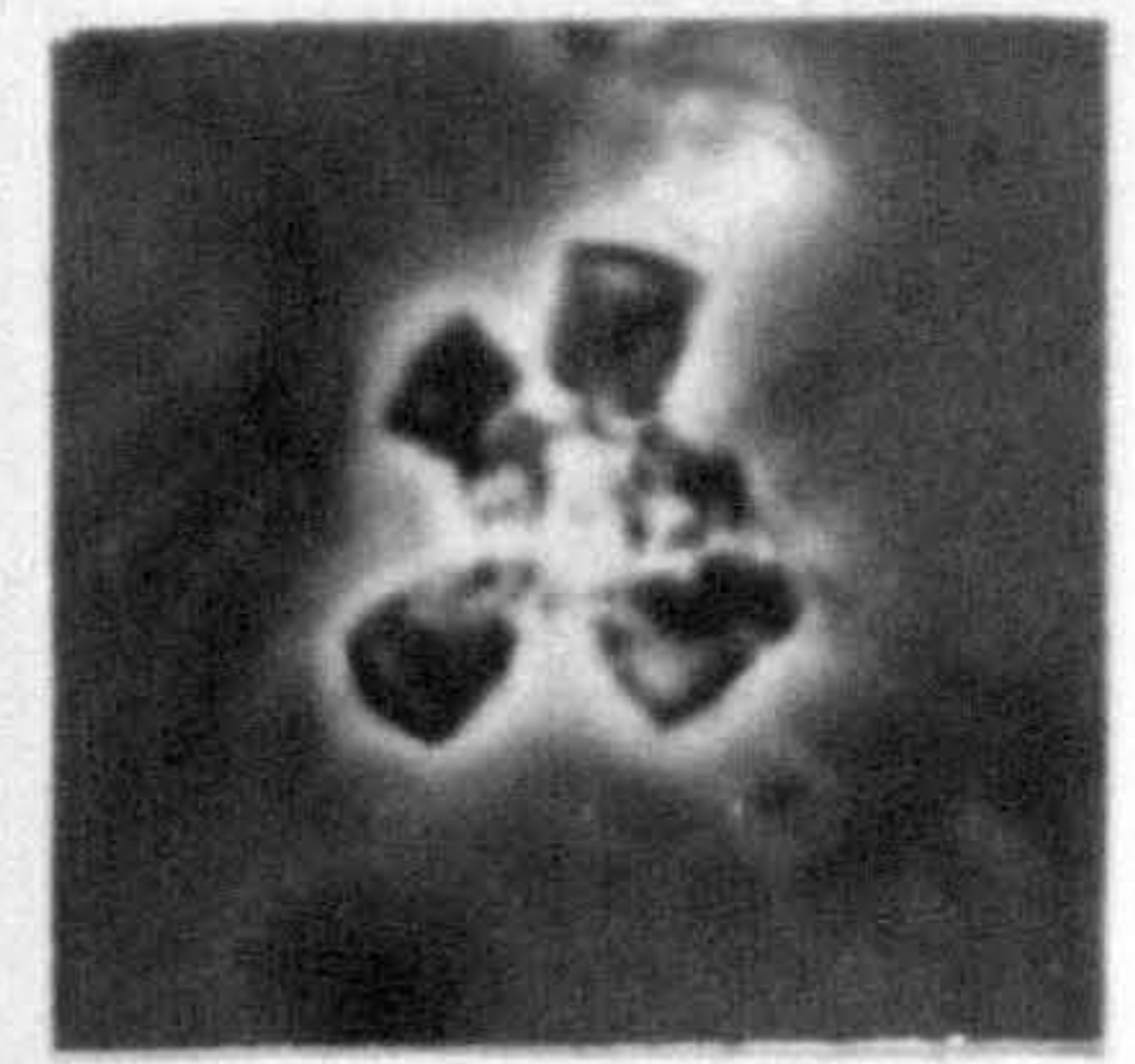
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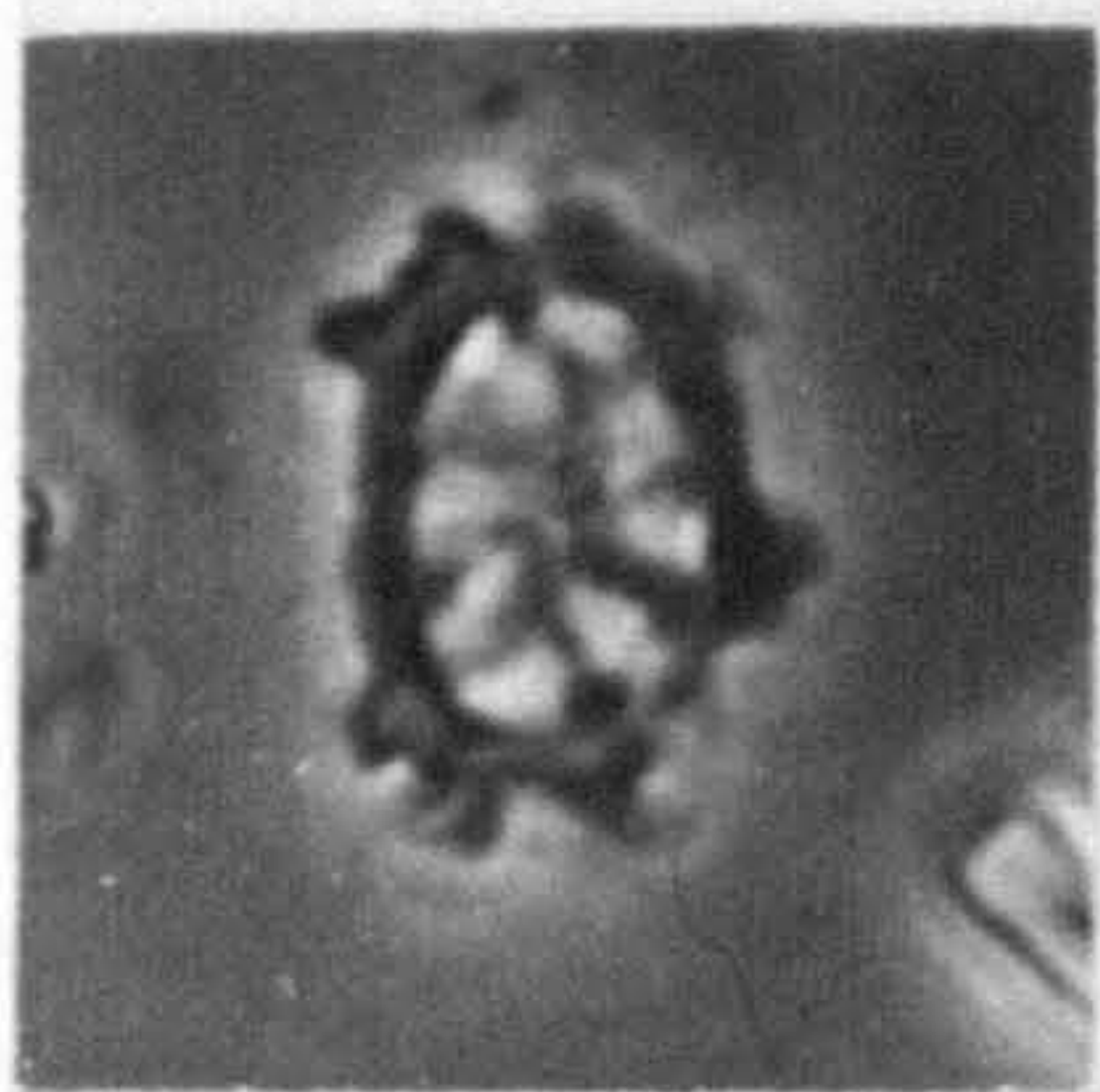
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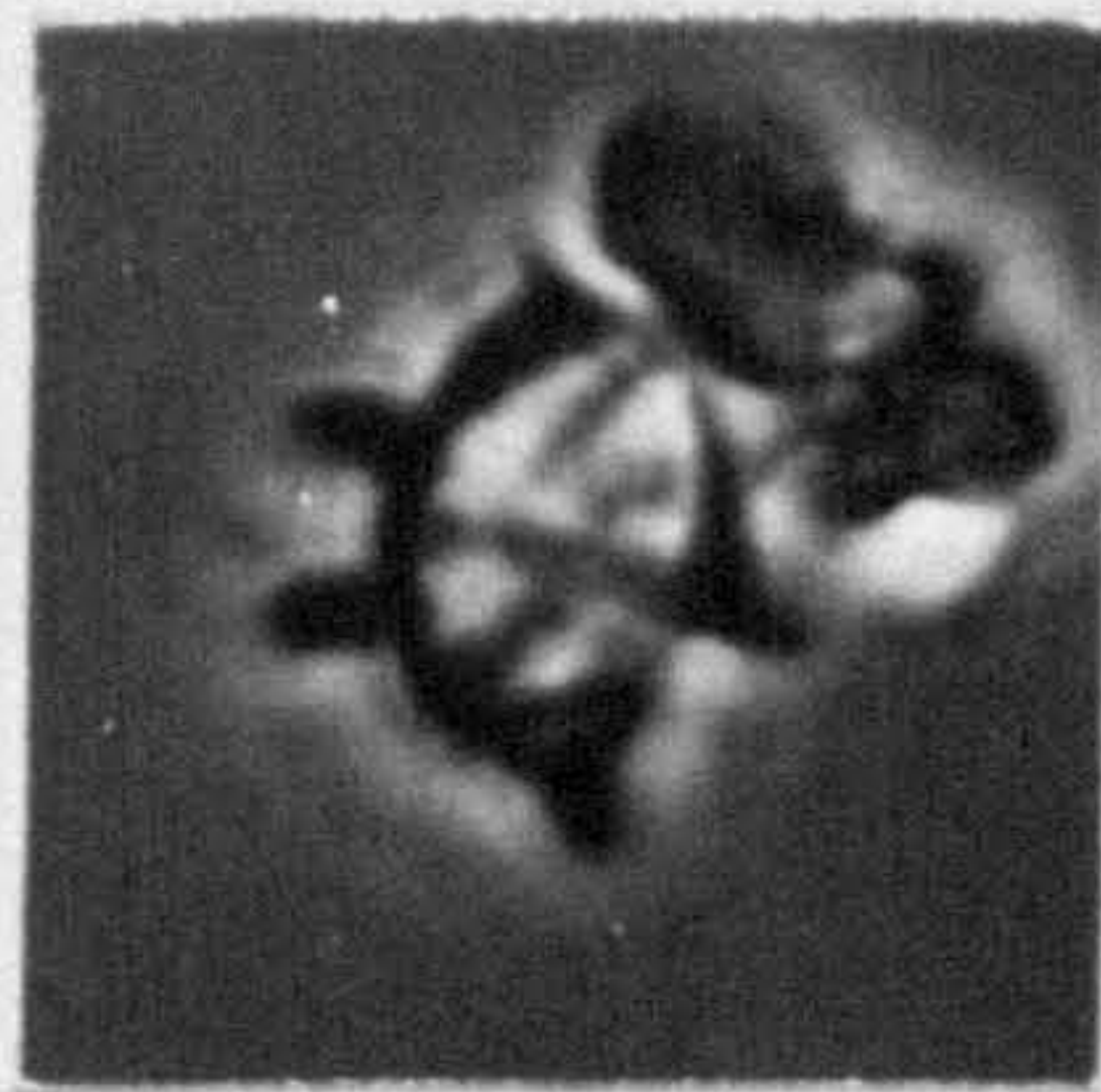
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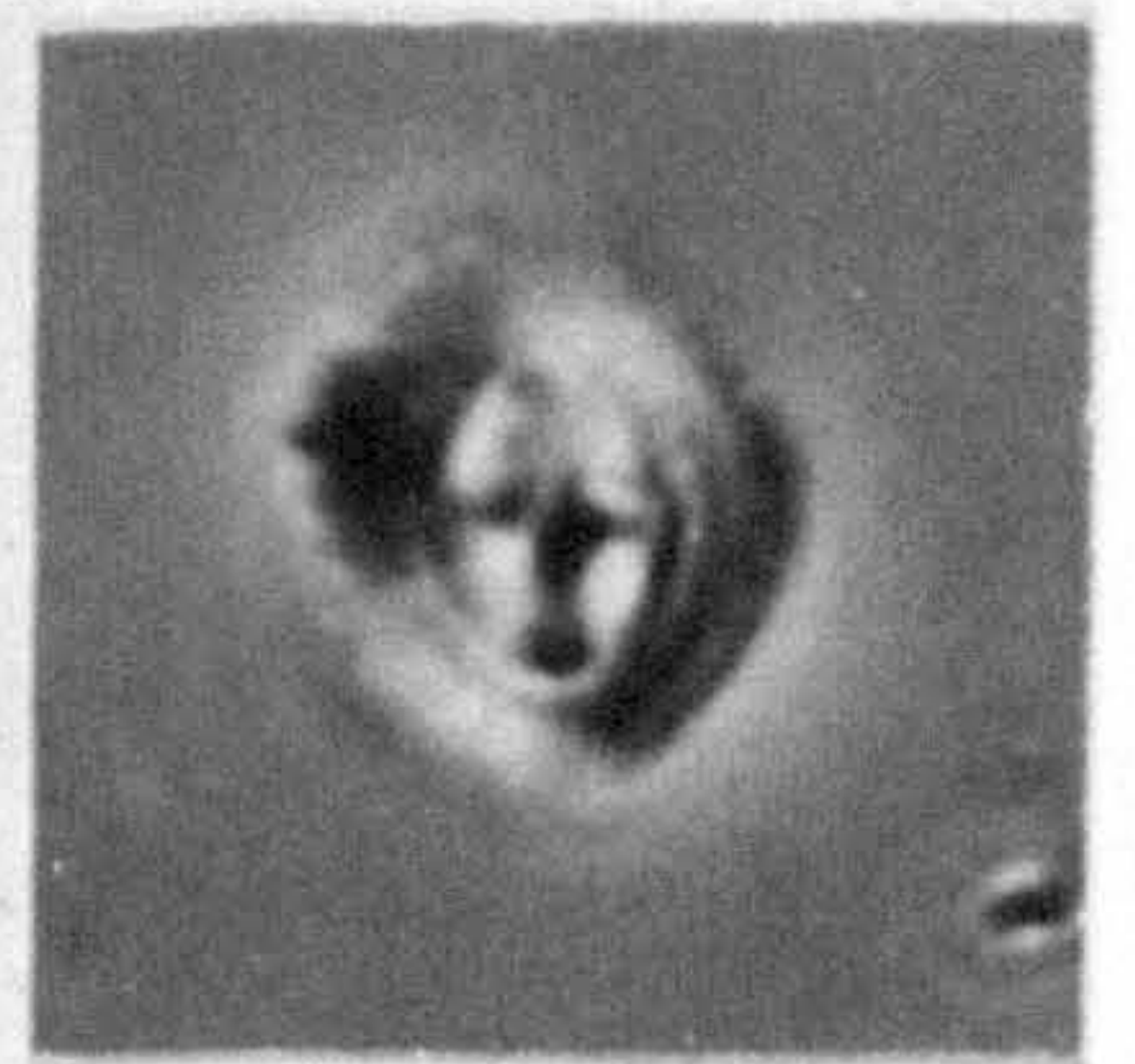
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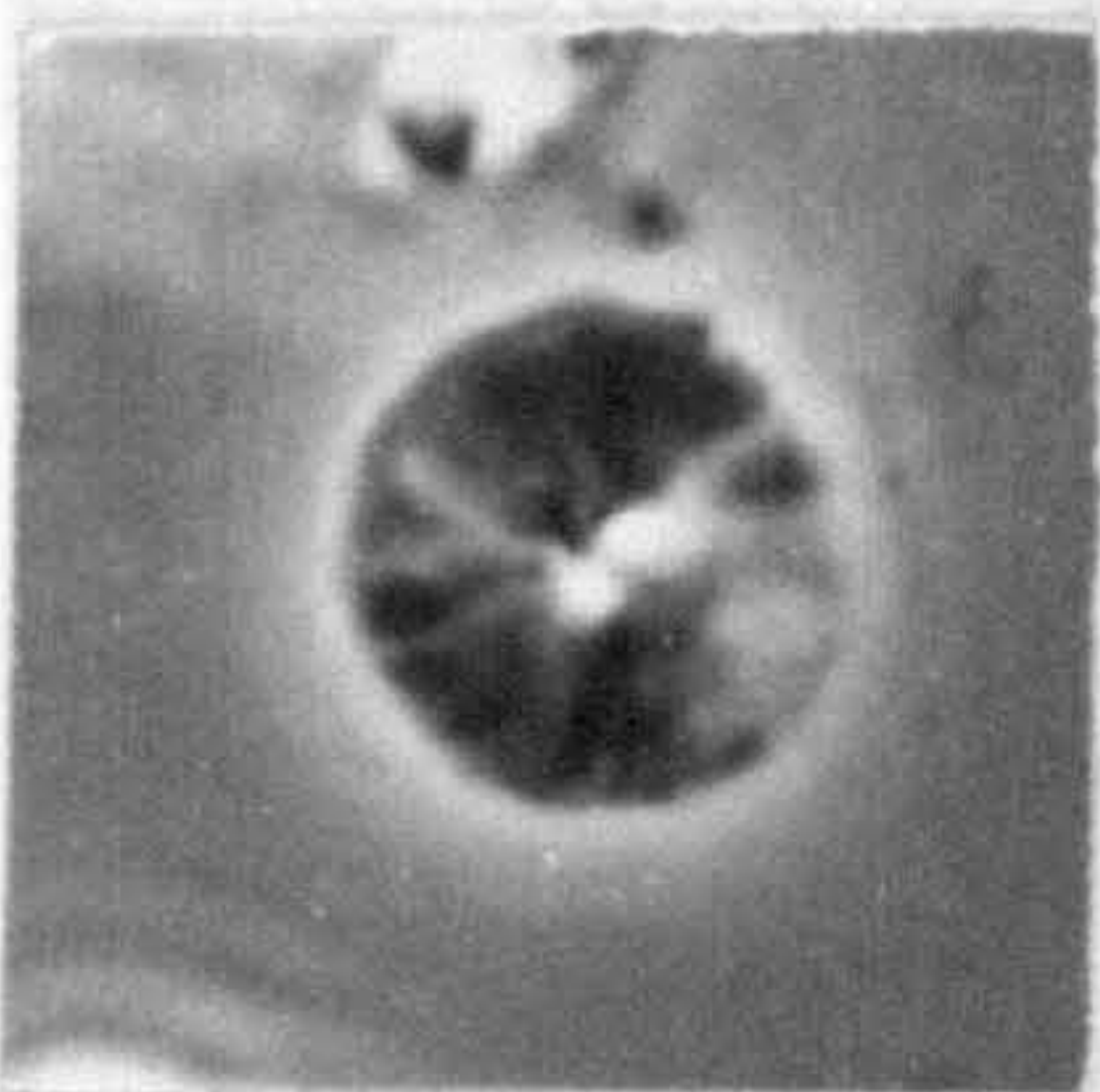
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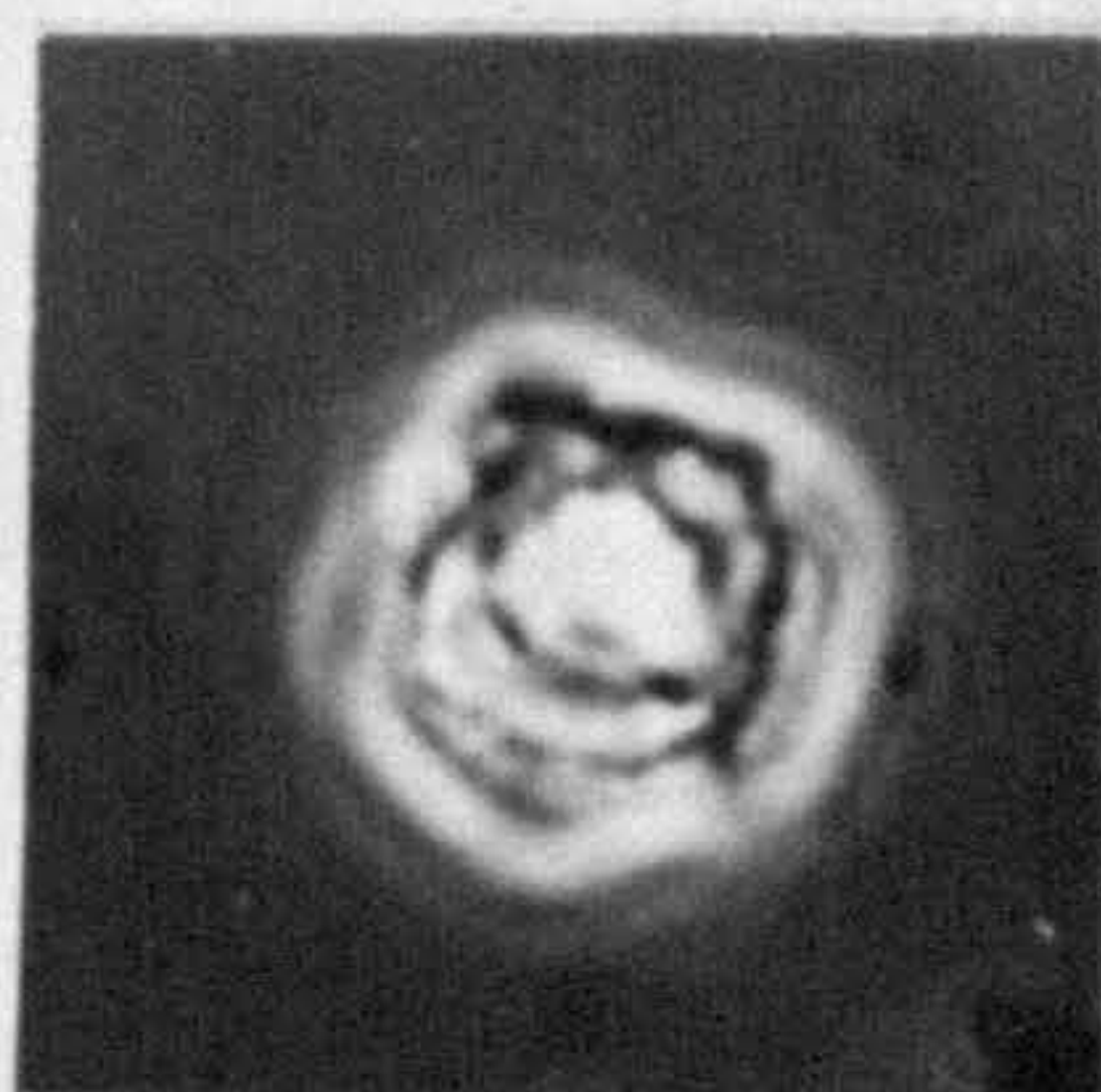
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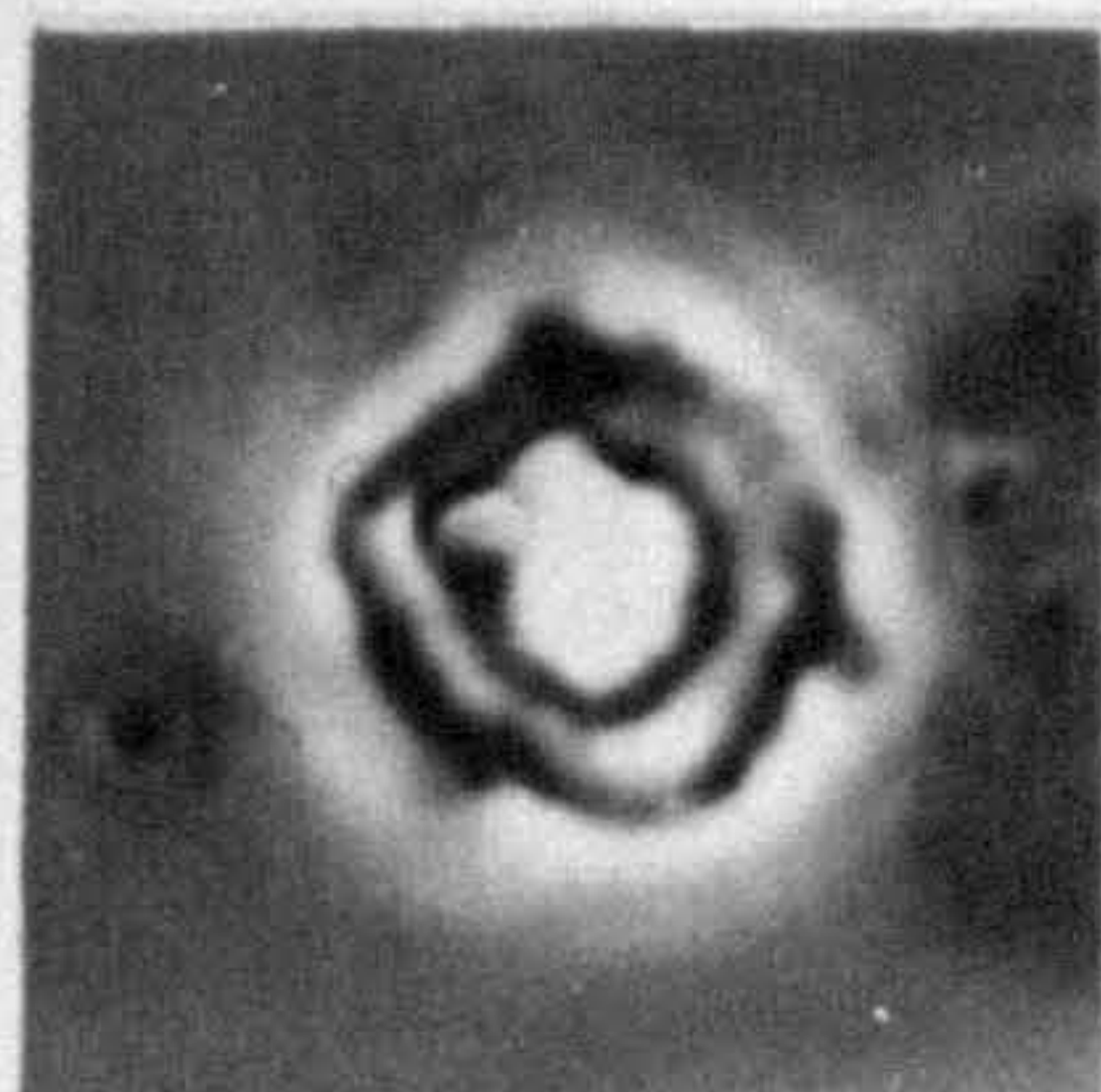
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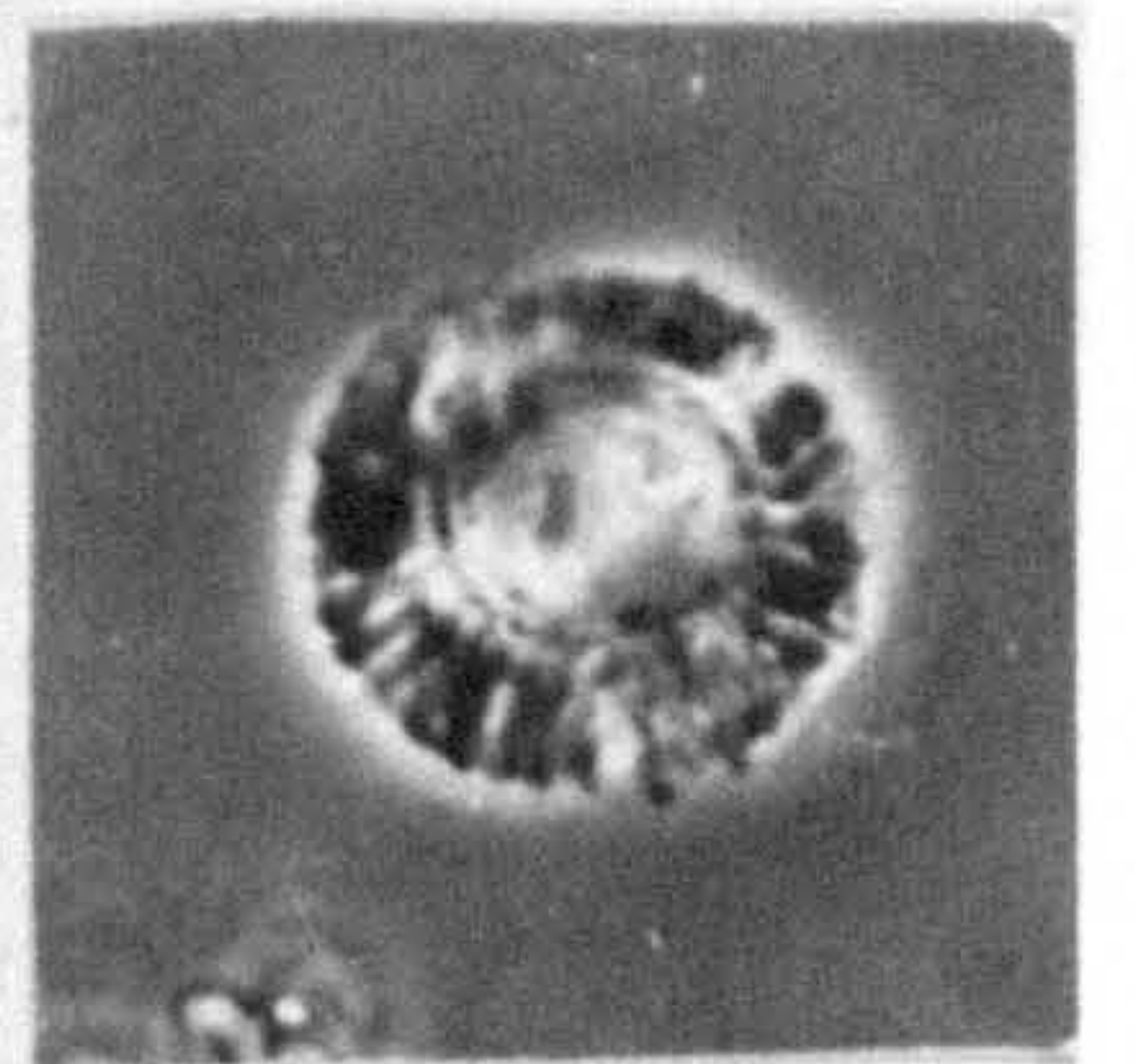
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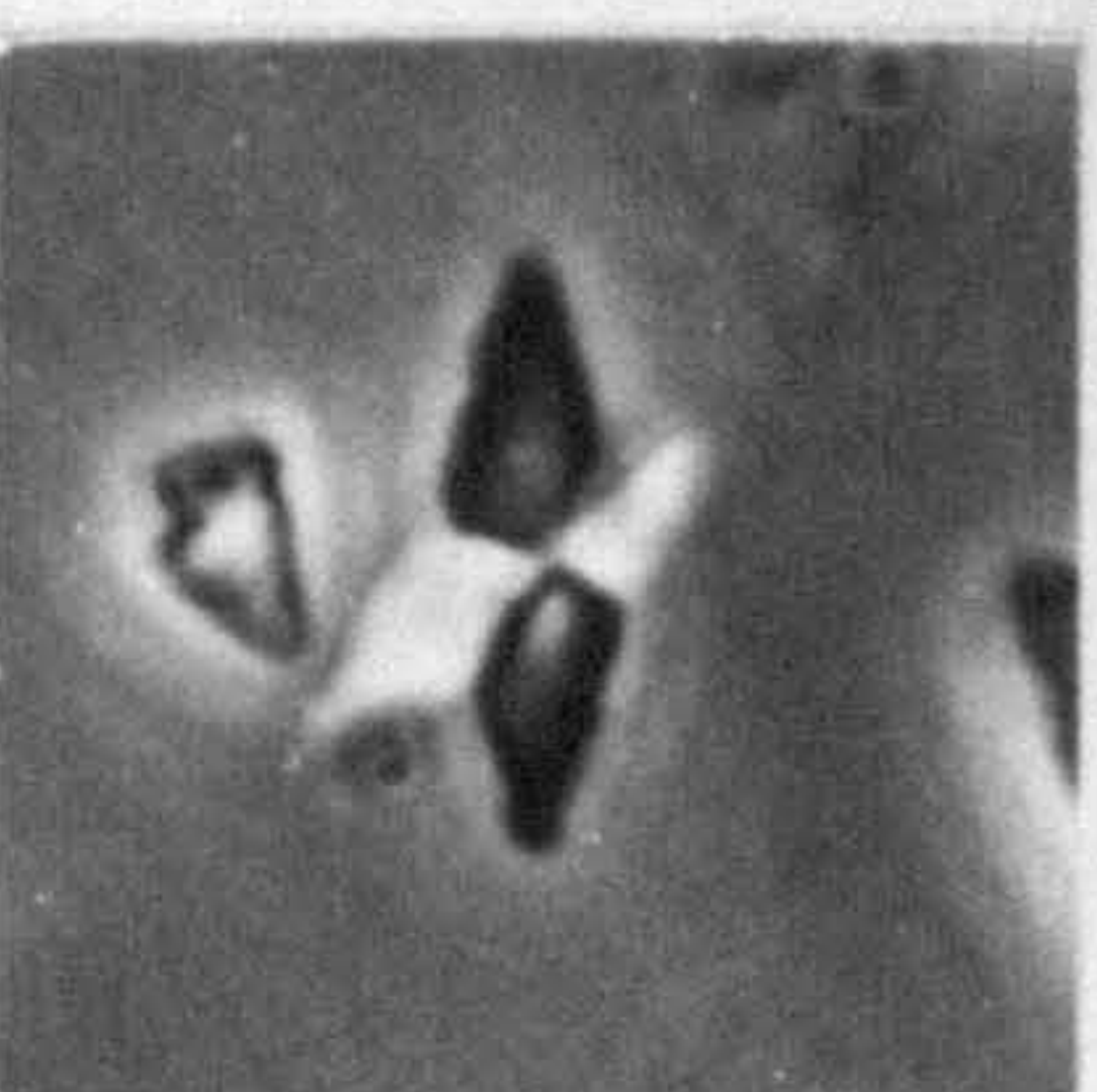
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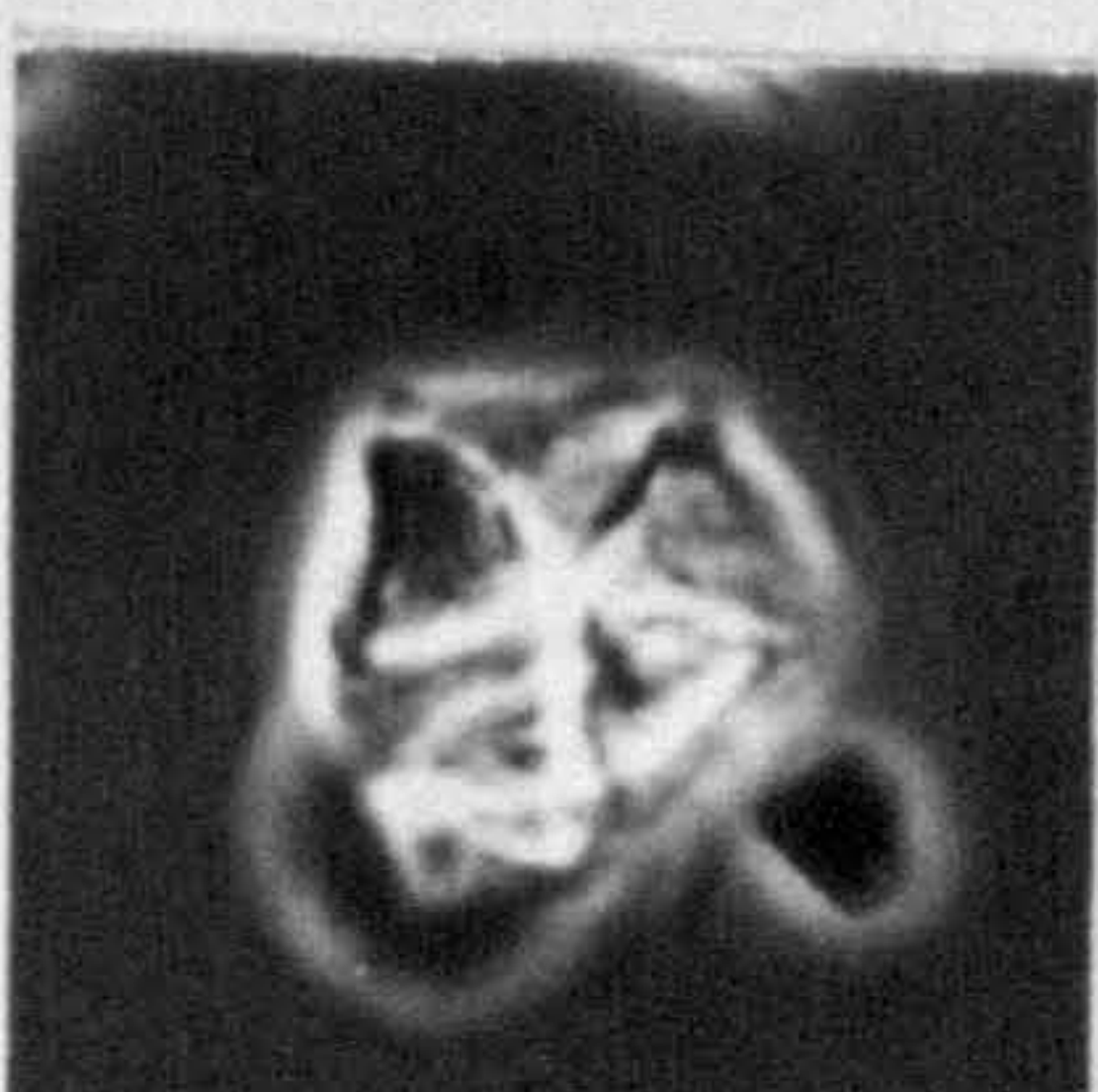
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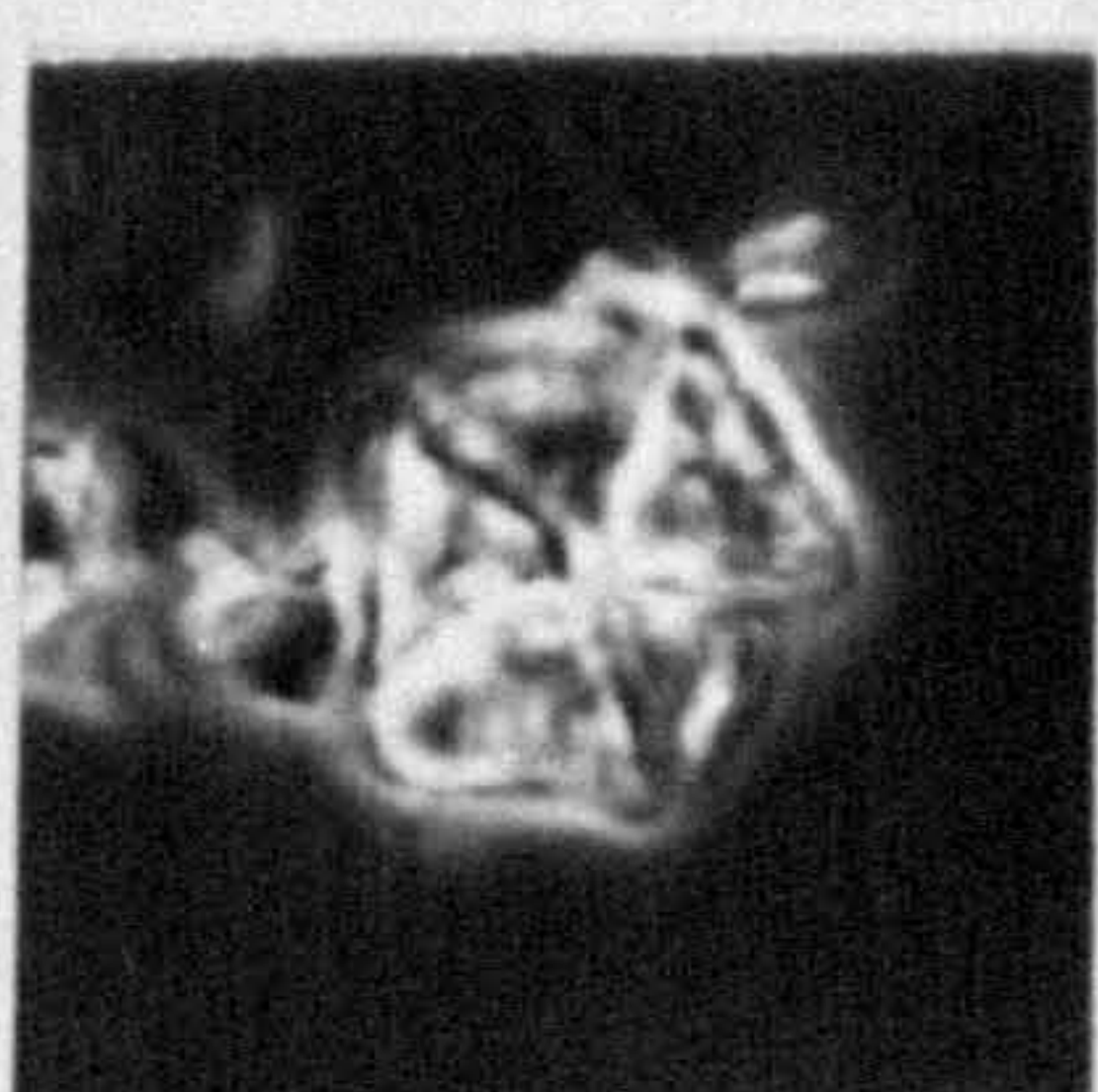
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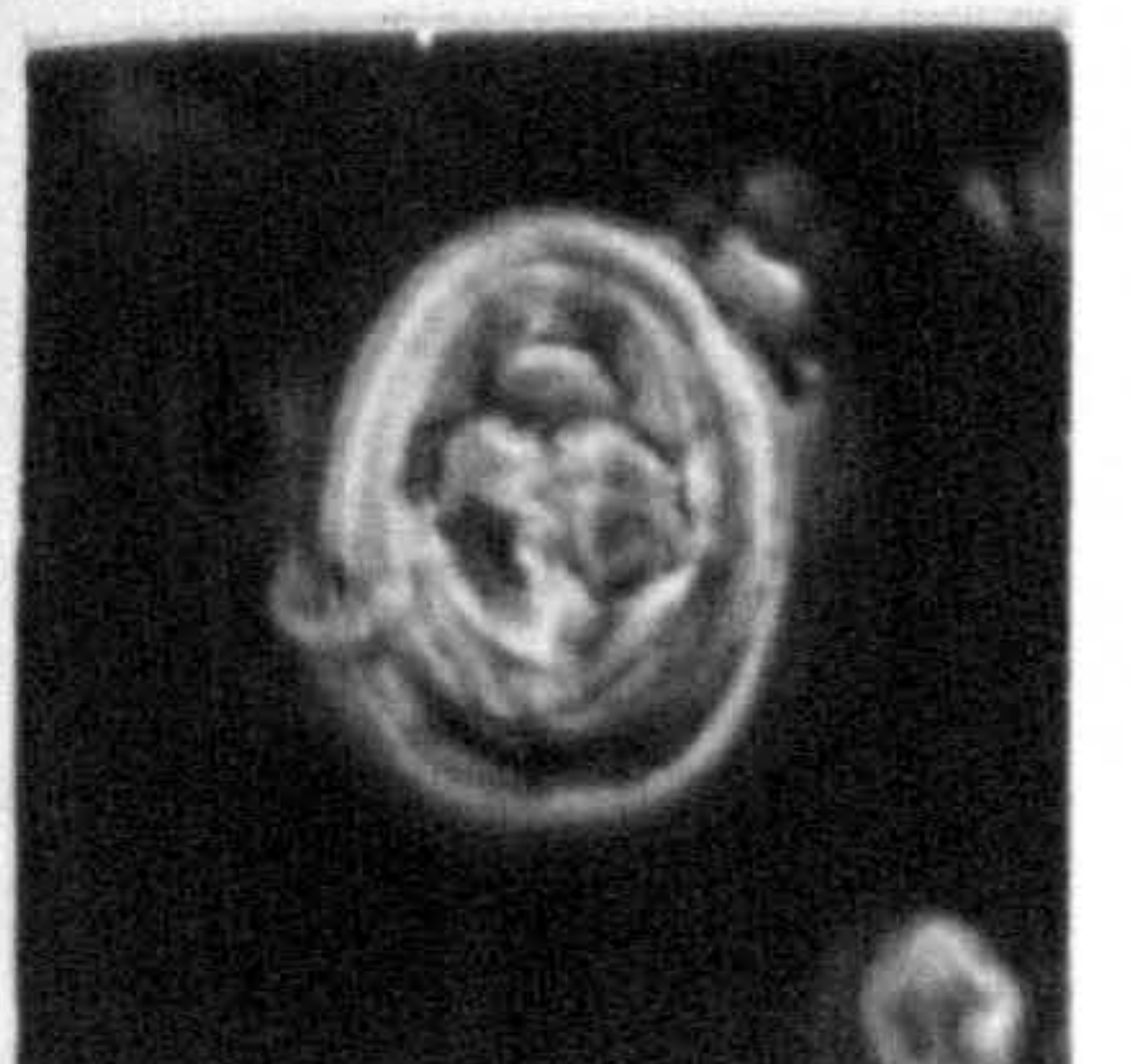
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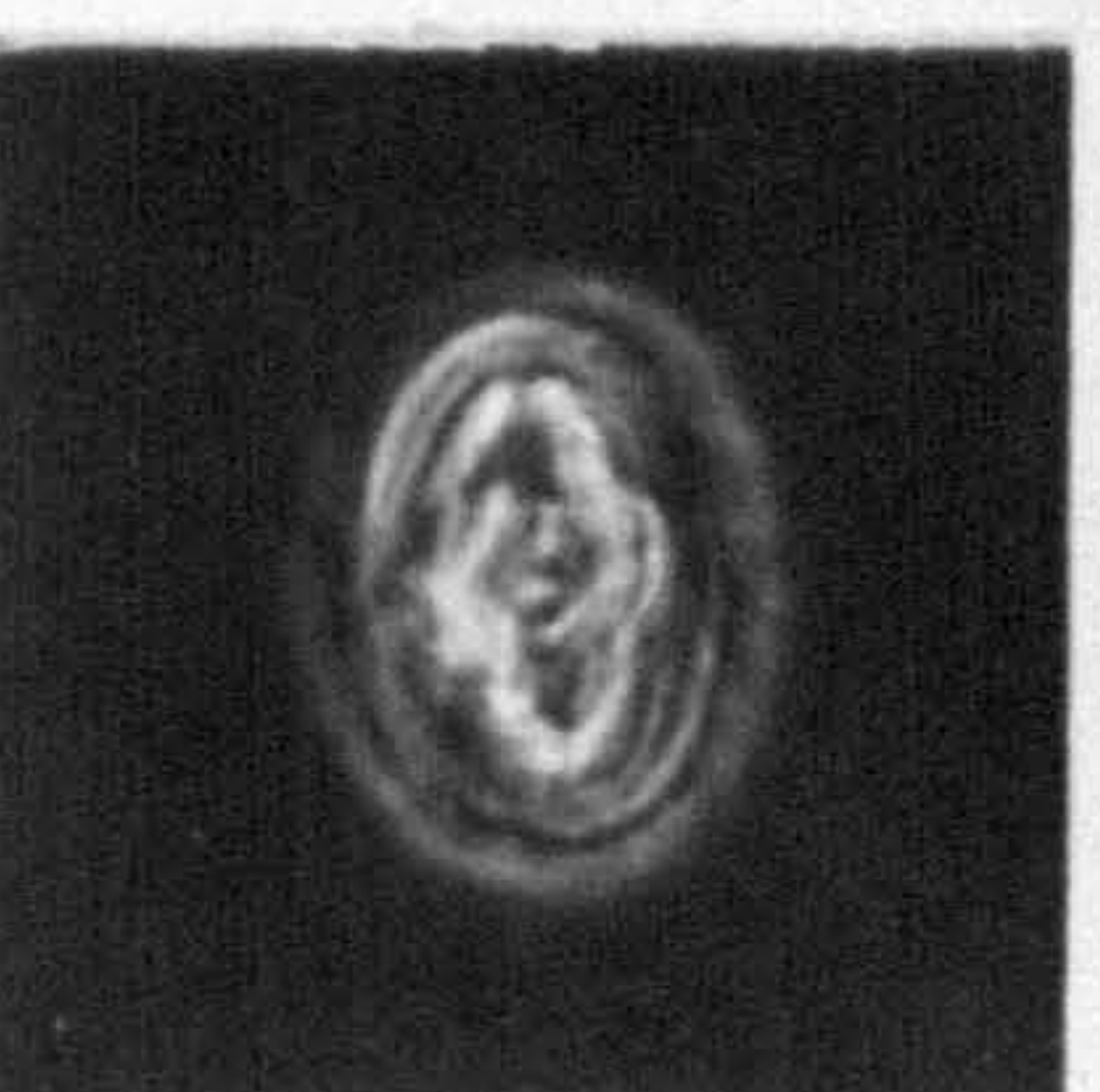
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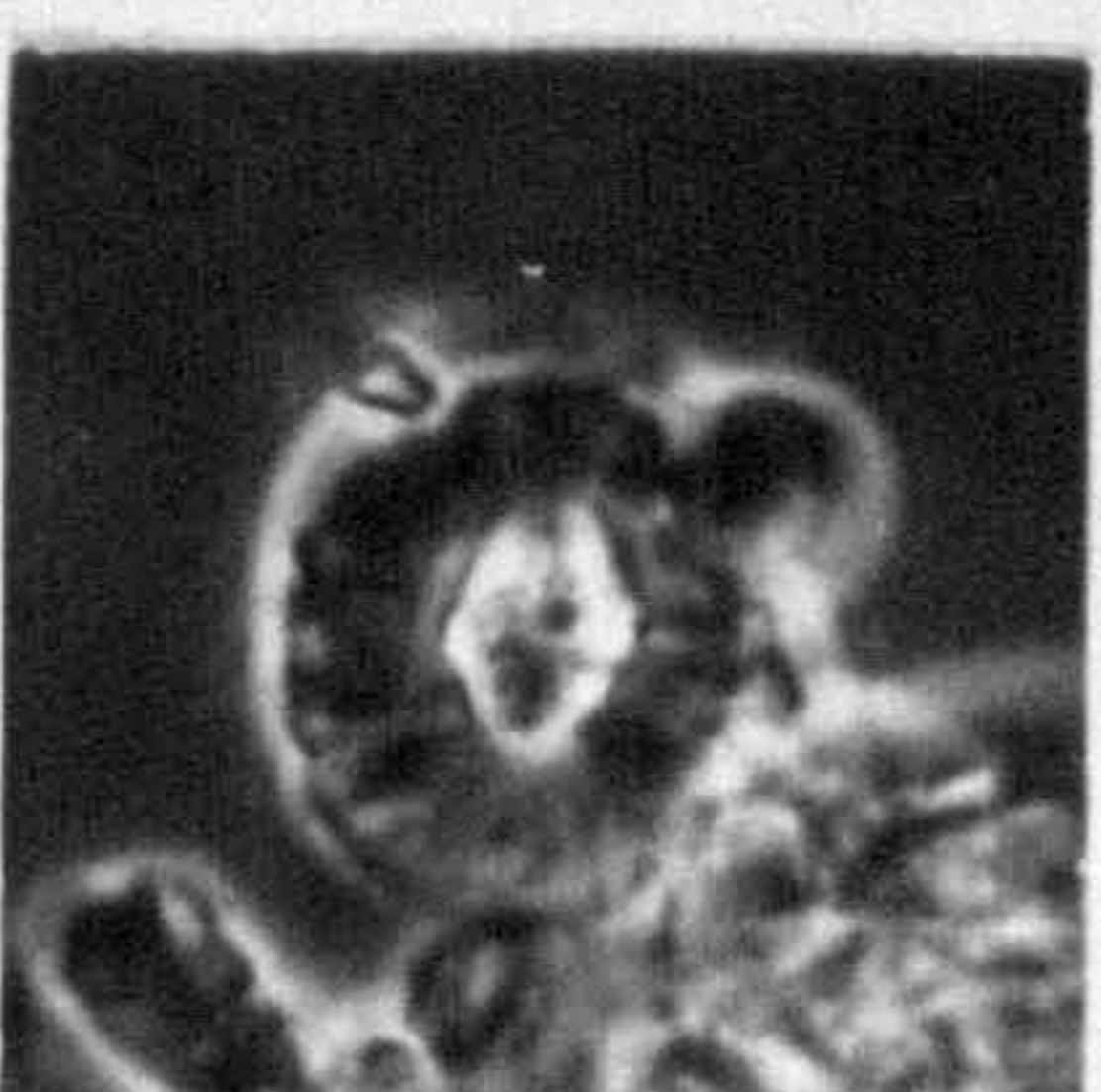
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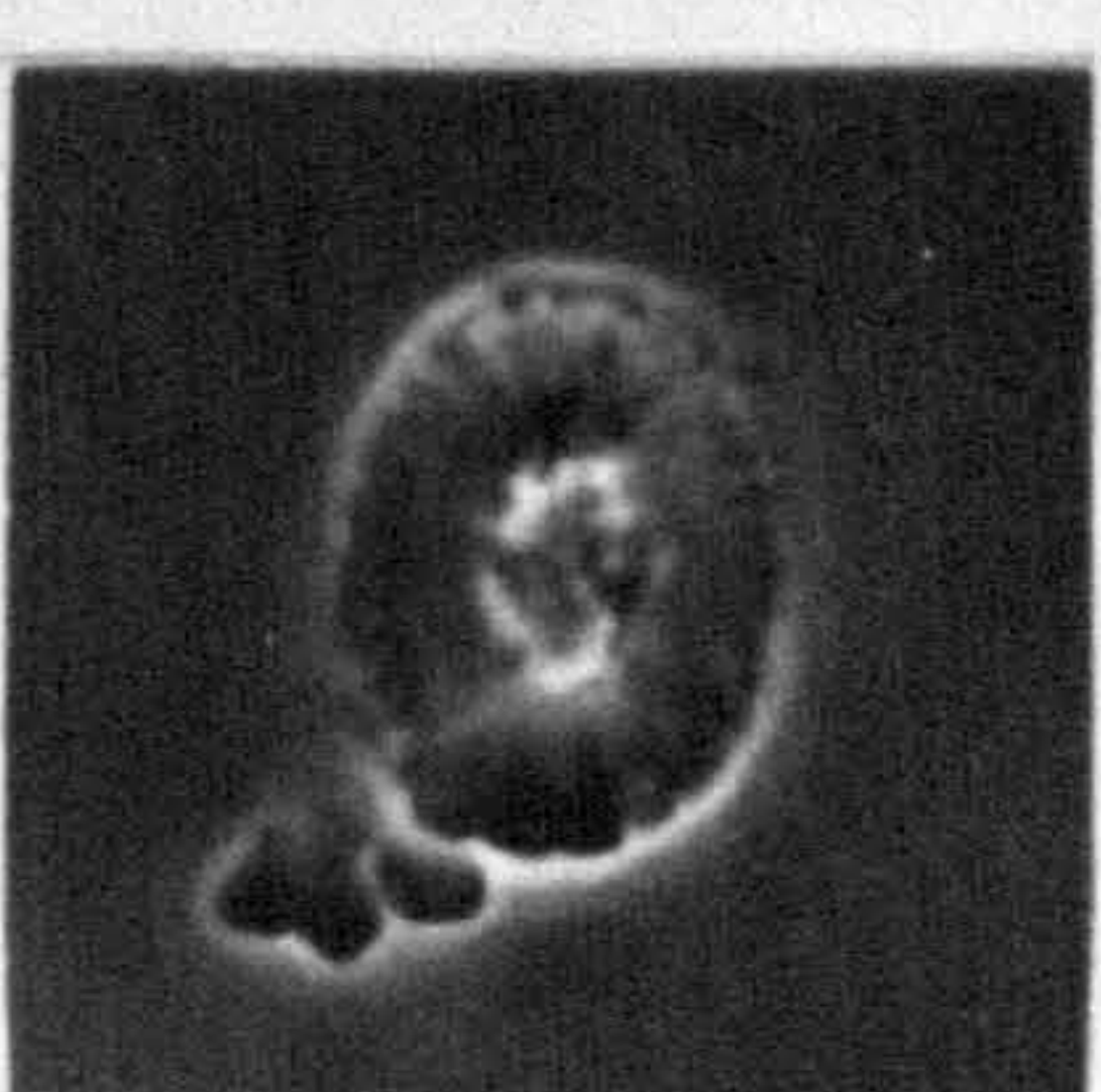
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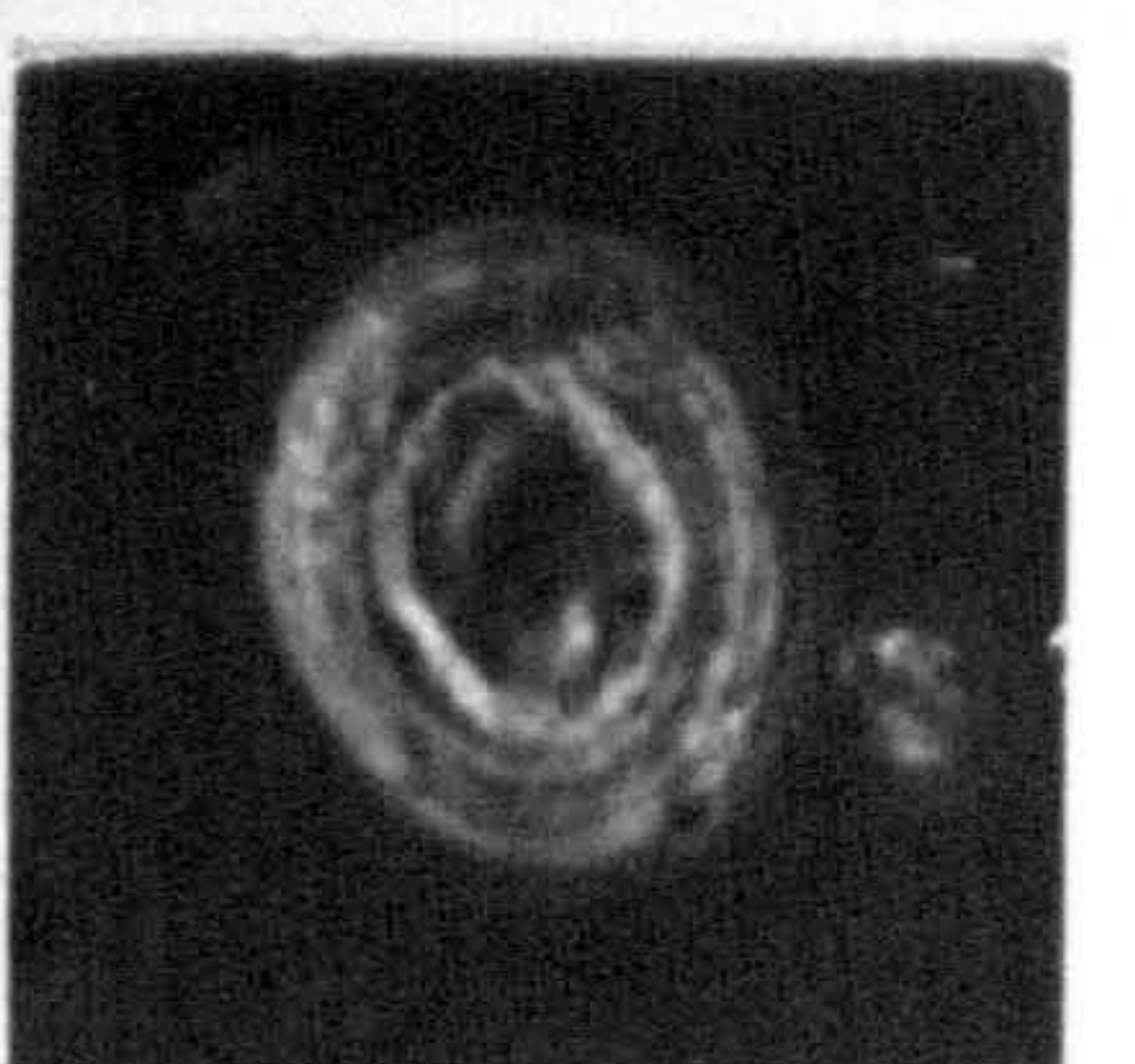
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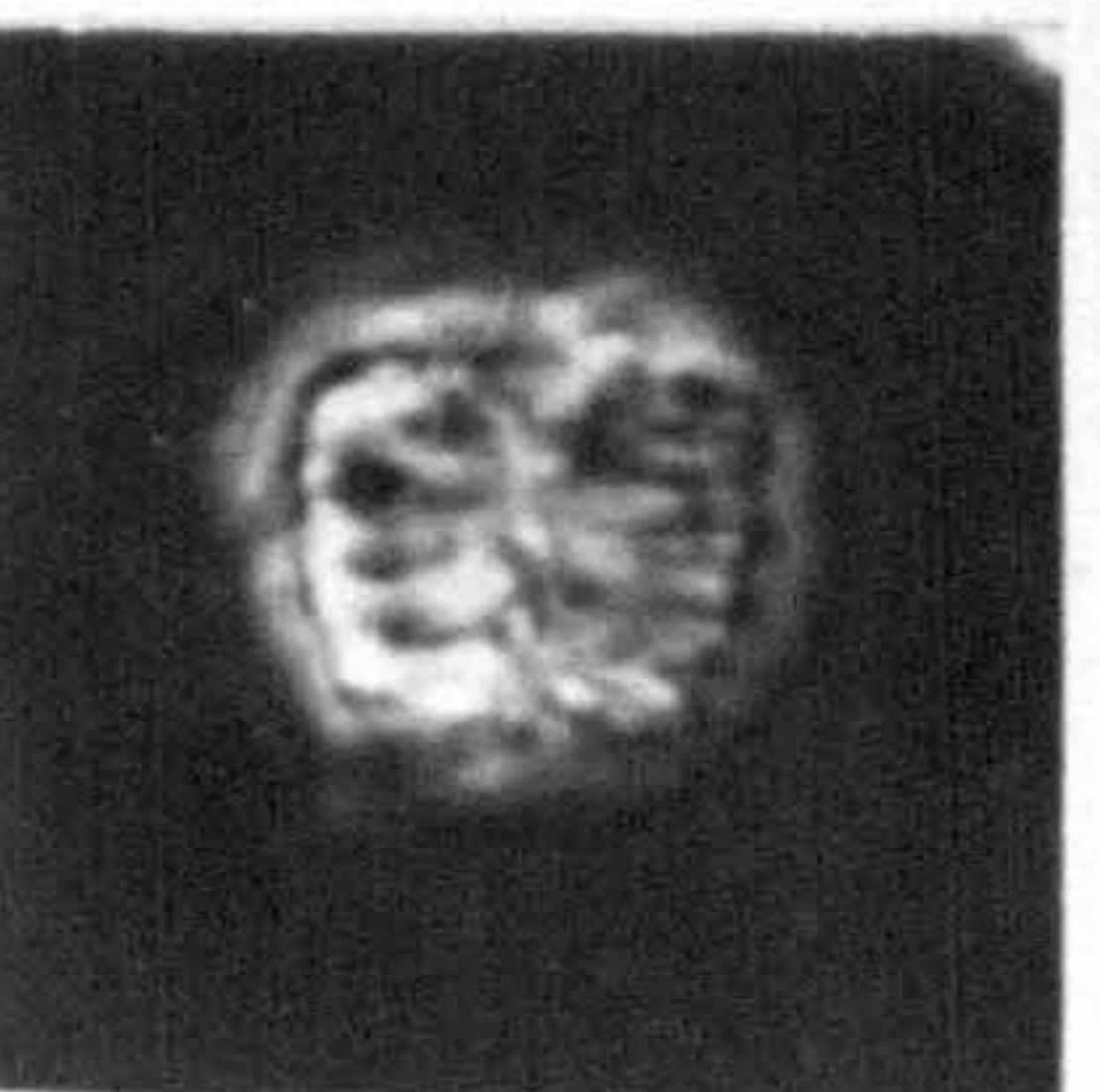
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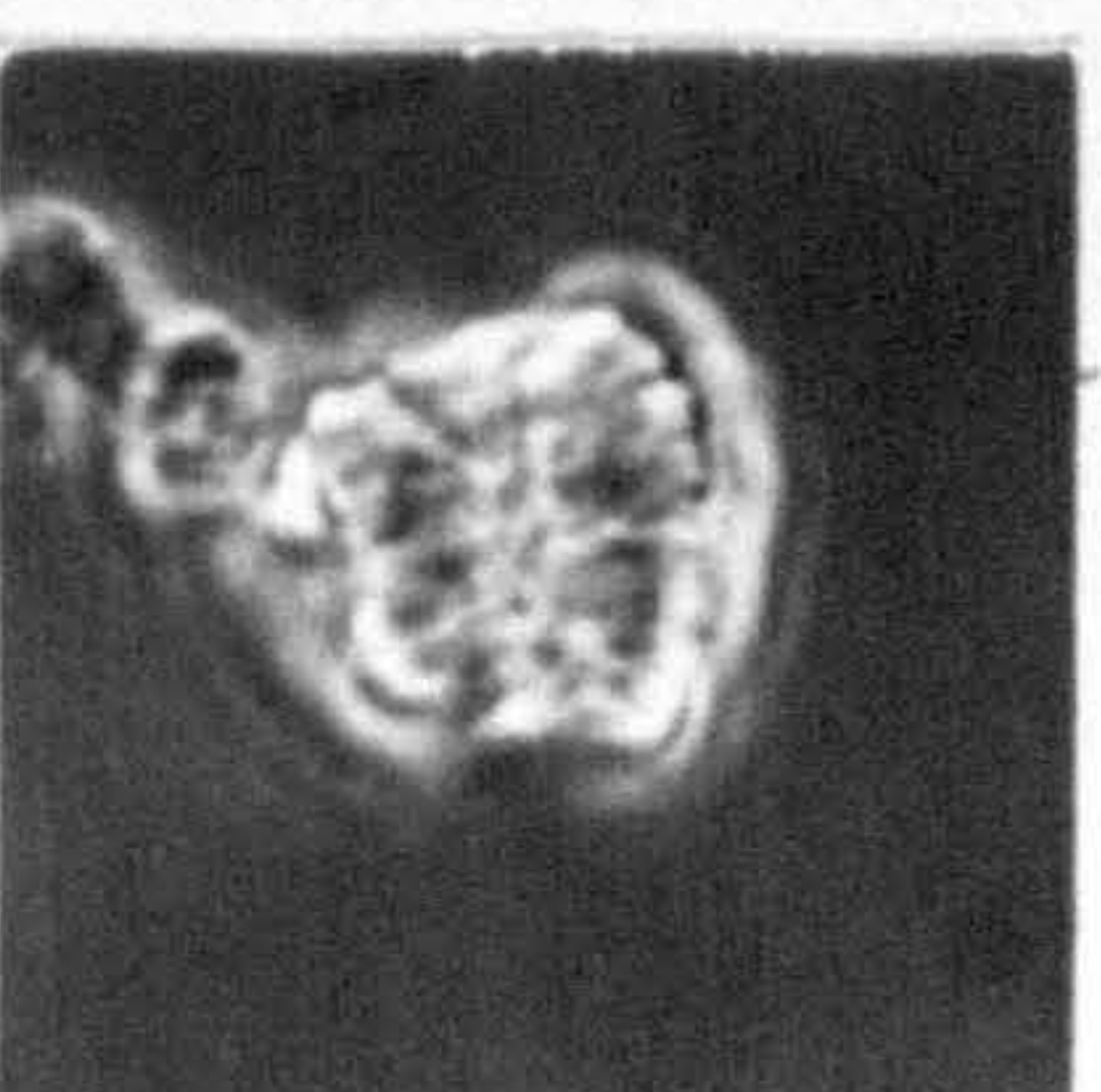
19



20



21



22



23



24

Plate 1

All specimens from Brenha Road section

- Fig. 1 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD
Oblique view
Hypotype UCL-67-18
Upper Toarcian, $\times 1200$
- Fig. 2 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD
Proximal side
Hypotype UCL-61-10
Upper Toarcian, $\times 2100$
- Fig. 3 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD
Oblique view
Hypotype UCL-61-12
Upper Toarcian, $\times 2800$
- Fig. 4 *Ethmorhabdus* aff. *E. gallicus* NOËL
Distal side
Hypotype UCL-63-22
Pliensbachian (Ibex Zone), $\times 5900$
- Fig. 5 *Ethmorhabdus* aff. *E. gallicus* NOËL
Proximal side
Hypotype UCL-57-2
Pliensbachian (Ibex Zone), $\times 5900$
- Fig. 6 *Ethmorhabdus* aff. *E. gallicus* NOËL
Distal side
Hypotype UCL-57-3
Pliensbachian (Ibex Zone), $\times 8500$
- Fig. 7 *Biscutum ellipticum* (GORKA) GRÜN & ALLEMANN
Distal side
Hypotype UCL-64-35
Pliensbachian (Spinatum Zone), $\times 8600$
- Fig. 8 *Calyculus pugnatum* GRÜN, PRINS & ZWEILLI
Proximal side
Hypotype UCL-64-2
Pliensbachian (Margaritatus Zone), $\times 4000$
- Fig. 9 *Calyculus cribrum* NOËL
Proximal side
Hypotype UCL-63-9
Pliensbachian (Ibex Zone), $\times 6000$
- Fig. 10 *Parhabdolithus marthae* DEFLANDRE
Oblique view
Hypotype UCL-56-29
Upper Sinemurian, $\times 5900$
- Fig. 11 *Podorhabdus cylindratus* NOËL
Proximal side
Hypotype UCL-60-10
Upper Toarcian, $\times 4300$
- Fig. 12 *Discorhabdus patulus* (DEFLANDRE) NOËL
Oblique view
Hypotype UCL-66-15
Upper Toarcian, $\times 4500$

Plate 2

All specimens from Brenha Road section

Discorhabdus ignotus (GORKA) PERCH-NIELSEN

- Fig. 1 Proximal side
Hypotype UCL-65-19
Upper Toarcian, × 6400
- Fig. 2 Proximal side
Hypotype UCL-56-8
Pliensbachian (Ibex Zone), × 5500
- Fig. 3 Proximal side
Hypotype UCL-65-26
Upper Toarcian, × 9500
- Fig. 4 Proximal side
Hypotype UCL-66-30
Upper Toarcian, × 5800
- Fig. 5 Proximal side
Hypotype UCL-66-11
Upper Toarcian, × 6600
- Fig. 6 Proximal side
Hypotype UCL-67-19
Upper Toarcian, × 6000
- Fig. 7 Distal side
Hypotype UCL-56-32
Upper Toarcian, × 5500
- Fig. 8 Proximal side
Hypotype UCL-67-20
Upper Toarcian, × 6600
- Fig. 9 Proximal side
Hypotype UCL-63-26
Pliensbachian (Ibex Zone), × 6500
- Fig. 10 Oblique view
Hypotype UCL-60-22
Upper Toarcian, × 5700
- Fig. 11 Oblique view
Hypotype UCL-61-4
Upper Toarcian, × 6200

Plate 3

All specimens from Brenha Road section
All light micrographs $\times 1300$

- Fig. 1 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD
Hypotype UCL-81-4
Upper Toarcian
- Fig. 2 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD
Hypotype UCL-74-31
Pliensbachian (Margaritatus Zone)
- Fig. 3 *Podorhabdus macrogranulatus* PRINS
Hypotype UCL-77-5
Upper Toarcian
- Fig. 4 *Ethmorhabdus* aff. *E. gallicus* NOËL
Hypotype UCL-78-25
Pliensbachian (Davoei Zone)
- Fig. 5 *Ethmorhabdus* aff. *E. gallicus* NOËL
Hypotype UCL-80-4
Pliensbachian (Davoei Zone)
- Fig. 6 *Vekshinella quadriarcula* (NOËL) ROOD, HAY & BARNARD
Hypotype UCL-80-7
Pliensbachian (Davoei Zone)
- Fig. 7 *Biscutum ellipticum* (GORKA) GRÜN & ALLEMANN
Hypotype UCL-79-2
Upper Toarcian
- Fig. 8 *Calyculus* spp.
Hypotype UCL-80-11
Pliensbachian (Margaritatus Zone)
- Fig. 9 *Calyculus* spp.
Hypotype UCL-78-28
Pliensbachian (Davoei Zone)
- Fig. 10 *Crepidolithus crucifer* PRINS
Hypotype UCL-78-24
Pliensbachian (Ibex Zone)
- Fig. 11 *Crepidolithus crassus* (DEFLANDRE) NOËL
Hypotype UCL-79-16
Upper Sinemurian
- Fig. 12 *Crepidolithus cavus* PRINS
Hypotype UCL-78-29
Pliensbachian (Ibex Zone)

Plate 4

All specimens from Brenha Road section
All light micrographs $\times 1300$

- Fig. 1 *Discorhabdus tubus* NOËL
Hypotype UCL-77-2
Upper Toarcian
- Fig. 2 *Carinolithus superbus* PRINS
Hypotype UCL-78-13
Upper Toarcian
- Fig. 3 *Carinolithus superbus* PRINS
Hypotype UCL-81-11
Upper Toarcian
- Fig. 4 *Crucirhabdus primulus* PRINS
Hypotype UCL-75-19
Pliensbachian (Ibex Zone)
- Fig. 5 *Discorhabdus patulus* (DEFLANDRE) NOËL
Hypotype UCL-82-31
Upper Toarcian
- Fig. 6 *Parhabdolithus marthae* DEFLANDRE
Hypotype UCL-73-25
Upper Sinemurian
- Fig. 7 *Parhabdolithus liasicus* DEFLANDRE
Hypotype UCL-71-22
Pliensbachian (Jamesoni Zone)
- Fig. 8 *Parhabdolithus liasicus* DEFLANDRE
Hypotype UCL-79-15
Upper Sinemurian
- Fig. 9 *Diazomatolithus lehmani* NOËL
Hypotype UCL-82-35
Upper Toarcian
- Fig. 10 *Discorhabdus ignotus* (GORKA) PERCH-NIELSEN
Hypotype UCL-82-33
Pliensbachian (Spinatum Zone)
- Fig. 11 *Discorhabdus ignotus* (GORKA) PERCH-NIELSEN
Hypotype UCL-73-30
Pliensbachian (Jamesoni Zone)
- Fig. 12 *Tubirhabdus patulus* PRINS
Hypotype UCL-73-22
Pliensbachian (Jamesoni Zone)